LEADLESS DECORATIVE TILES, FAIENCE AND MOSAIC

Leadless Decorative Tiles, Faience, and Mosaic

COMPRISING NOTES AND EXCERPTS ON THE

HISTORY, MATERIALS, MANUFACTURE & USE

OF

Ornamental Flooring Tiles, Ceramic Mosaic, and Decorative Tiles and Faience

WITH COMPLETE SERIES OF RECIPES FOR TILE-BODIES, AND FOR

Leadless Glazes and Art-Tile Enamels

BY

WILLIAM JAMES FURNIVAL

RESEARCH CERAMIST AND CONSULTING POTTER; HONOURS MEDALLIST IN POTTERY AND PORCELAIN, CITY AND GUILDS OF LONDON INSTITUTE
AUTHOR OF "RESEARCHES ON LEADLESS GLAZES," "STAFFORDSHIRE POTTERIES SLOP FLINT AND STONE TRADE CALCULATOR," "EQUIVALENT MEASURES OF CLAY SLIPS," ETC.

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To

Manufacturers of Decorative Tiles and Faience throughout the world who desire to protect their operatives from Lead Poisoning, and to all who are interested in the highest welfare of the Ceramic Industry, this volume is most respectfully addressed

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The especially gracious and most courteous acceptance and acknowledgment of a copy of my former work, *Researches on Leadless Glazes*, by his Imperial Majesty King Edward VII., and also by His Royal Highness the Prince of Wales (then Duke of Cornwall and York), the yet earlier encouragement by Her Grace the Duchess of Sutherland, and by the late respected The Right Honourable the Marquess of Salisbury, and other distinguished and learned personages, together with the very complimentary character of the review of the former publication by the Editors of the *Lancet*, leave me no room to doubt that this further contribution toward the elimination of plumbism from the ceramic industry will be generally approved.

W. J. F.

STONE, STAFFORDSHIRE,
Anno Domini 1904.

ABBREVIATIONS

W.M.F.P. Coll.	Prof. W. M. Flinders Petrie's Collection (London).
J.W. Coll.	Mr. John Ward's Collection (Belfast).
Forrer Coll.	Dr. Forrer's Collection (Strassburg).
V. & A. M.	Victoria and Albert Museum, London.
B.M.	British Museum, London.
W.N.F. Coll.	W. Norman Furnival's Collection (Stone).
E.E. Fund	Egyptian Exploration Fund.
E.R.A.	Egyptian Research Account.
Trans. Am. C.S.	*Transactions of the American Ceramic Society.*
Trans. N.S.C.S.	*Transactions of the North Staffordshire Ceramic Society.*
Trans. A.I.M.E.	*Transactions of the American Institute of Mining Engineers.*
Jour. Soc. Arts	*Journal of the Society of Arts*, London.
Mus. Pract. Geol.	Museum of Practical Geology, Jermyn St., London.

CORRECTIONS

On Plate XIII.	For "boarder" in the legend, read "border"
On page 204	For "Boulanger" in legend, fig. 131, read "Boulenger."
On page 230	For "£1,000,000," read "$1,000,000."
On page 624	For "No. 6" on line 21, read "No. 5."
On page 679	For "£7 14 0" read "£7 4 0."
On page 686	For "glaze-pan" on line 30, read "glaze or colour pan."

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LEADLESS DECORATIVE TILES, FAIENCE, AND MOSAIC

CHAPTER I.

"RAISON D'ÊTRE."

"*If preventable, why not prevented?*" (*H.M. King Edward VII. when Prince of Wales*).

CONTENTS.—Object—Parliament and lead-poisoning—Preventive measures—Arbitration proceedings, November 1901—Manufacturers' opinions—Outsiders'—Commercial aspect—Oven fumes—Looking backward—Public opinion—Adjourned arbitration—The award—Conclusions.

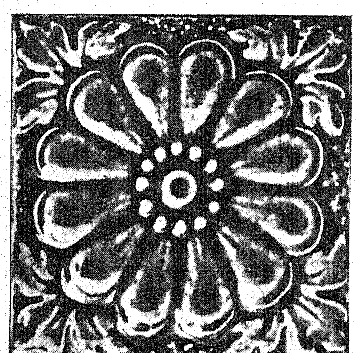


FIG. 1.—Leadless glazed embossed tile.

THE object in writing and publishing the following pages is not simply to issue a dissertation upon the history and manufacture of decorative faience and mosaic—although this and other matters have been introduced to extend the usefulness of the volume;—the principal aim is, to place before those who are either interested in, or engaged in these manufactures throughout the world, a series of recipes for the preparation of leadless glazes for the purpose, and so to assist in eliminating lead-poisoning from the industry.

Legislative coercion excites opposition, and, to be just and beneficent, requires consummate judgment in its exercise. A more effectual course to pursue in endeavouring to bring about the desired change is, perhaps, to discover and publish less injurious glazes and enamels than those in general use, and let competition, common sense, and public opinion do the rest.

In a former publication—*Researches on Leadless Glazes*—written six years ago, it was shown, on the authority of Sir Matthew White Ridley, that during

two and a half years, between 1895 and 1898, the total number of reported cases of lead-poisoning in the manufacture of earthenware and china, among women and girls alone, had been 591, equivalent to a yearly average of about 230.

That these figures have now declined to about 47 per annum, or a total of 87 for *both sexes* per annum (increased to 97 in 1903), cannot logically be said to prove that further attention to the matter is unnecessary; it rather shows conclusively the value of public discussion of a grievance, and—to make use of the language of the late respected William Woodall, Esq., M.P., himself an eminent manufacturer of earthenware —"more than justify the concern and solicitude that has found expression in Press and Parliament."

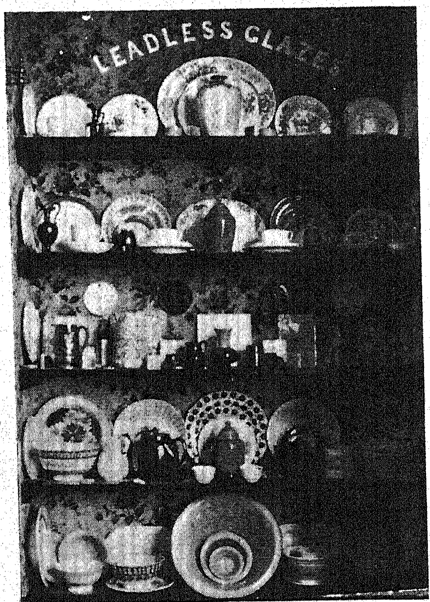


FIG. 2.—Leadless glazed specimens.

The subject of "lead-poisoning" having been so frequently discussed by Parliament, by the Home Office, by the Press, by manufacturers' associations, by medical and clerical assemblies, by learned societies, and other public bodies, it will be generally conceded that there is room for technical publications directed towards its absolute and final elimination on the line Professor Thorpe has asserted is the only one by which complete immunity is ever likely to be attained, namely, by the discontinuance of the use of lead compounds.

Several, if not many, tile and faience manufacturers have at various times made or caused to be made numerous practical experiments in this direction, but they do not publicly give the industry in general an opportunity of profiting by their labours.

So far, at least, *Researches on Leadless Glazes* apparently remains the only work in English especially devoted to this phase of the subject; and as the practical recipes therein suggested were for the most part applicable chiefly to general earthenware, chinaware, and similar pottery, further recipes were required for other classes of ceramic products in the manufacture of which different conditions prevailed, or the attainment of different objects was sought.

The increasing extent and complexity of the manufacture of tiles and faience for structural embellishment, and the fact that this branch of industry

was being conducted by the use of even greater proportions of lead compounds in the glazes and enamels than that of china and earthenware, appealed strongly for attention. Hence special researches were undertaken with redoubled vigour to discover if it were possible to reconstruct the glaze formula for decorative tiles in such a manner as to eliminate all salts of lead without deteriorating the effectiveness, utility, and durability of the product.

This, the writer claims, has now in a very large measure been accomplished, and the selected and experimentally tested results of the investigations are herein respectfully submitted to all whom it may concern. Not as absolutely perfected and cosmopolitan formulæ adapted to every individual requirement or fancy, but as reliable bases upon which, by slight modification, each manufacturer may prepare either coloured or colourless glazes, suited to his own special conditions and products—a starting-point, a helpful guide, a practical desk friend specially devoted to the subject. The writer is conscious of some imperfections, but most of these are believed to be susceptible of removal by the exercise of acquired operative skill in actual practice, when that practice is not antagonistic.

The recipes are given in commonplace industrial terms, so that anyone possessing reasonable knowledge of potters' materials and methods can straightway mix the ingredients and produce what is stipulated.

Preventive Measures.—Almost all concerned now admit that the compounds of lead have in the past been used excessively, and often in a more or less indiscreet manner; and efforts have been made to amend the methods so long sanctioned by injudicious custom. The best firms have erected fans for rapidly removing deleterious dust from the workrooms, provided overalls and ablutionary facilities, and arranged for occasional medical inspection, with the object of minimising the risks of lead-poisoning. Recognising the wisdom and advantage of such precautionary measures, the Home Office issued revised rules for regulating the conduct of the industry, so as to bring up all factories abreast to the requisite standard of hygienic efficiency; and established a system of medical examination, with powers of suspension, in certain cases, of workers exhibiting initial symptoms of plumbism; the happy result of these organised efforts, together with greater individual care by operatives and all concerned, being a marked decline in notified cases of lead-poisoning in potteries.

But other influences undoubtedly contributed an appreciable quota toward bringing about this welcome decline in the rate of sickness: for instance, the reduction by some manufacturers of the hitherto excessive proportion of lead salts in their glazes; the more frequent use of glaze compounds in which the lead salt has been judiciously fritted in certain special proportions with the object of reducing its rate of solubility; the partial return to the use of nature's

own lead salt—Galena; and last, but not least, the increasing use of lead-free glazes.

Proof of this exists in the fact that under the Earthenware and China Award (December 1901) Special Rules, undertakings received and certificates granted in pursuance of Rules 22, 23, and 24, up to the end of March 1903, were as under.

(*Published by permission of the Home Office.*)

Class of Ware.	Rule 22.	Rule 23.		Rule 24.
	"Leadless" Glaze.	(*a*) 5 per cent. Glaze.	(*b*) Moist. Ware Cleaning.	2 per cent. Glaze.
CHINA,	1	6	...	...
EARTHENWARE—				
General earthenware, without stated distinction of ware,	10	4	86	1 *
Do. do. including majolica ware,	...	1	9	...
Do. do. including majolica tiles,	...	...	3	...
Do. do. excluding majolica ware and tiles,	...	1	...	...
Do. do. including jet and Rockingham ware,	...	...	5	...
Do. do. excluding jet and Rockingham ware,	2	...	...	...
Do. do. including electrical fittings and china furniture,	...	...	1	...
Do. do. including sanitary ware,	...	...	4	...
TILES—				
Do. including majolica tiles,	...	...	27	...
Do. excluding majolica tiles and majolica ware,	1	...	...	...
MAJOLICA WARE,	...	...	2	...
JET AND ROCKINGHAM,	...	...	20	...
ELECTRICAL FITTINGS AND CHINA FURNITURE,	...	...	2	...
Do. do. including sanitary ware,	...	1	...	...
SANITARY WARE,	3	1	13	...
STONEWARE,	2	...	...	...
Total number of certificates,	19	14	172	1

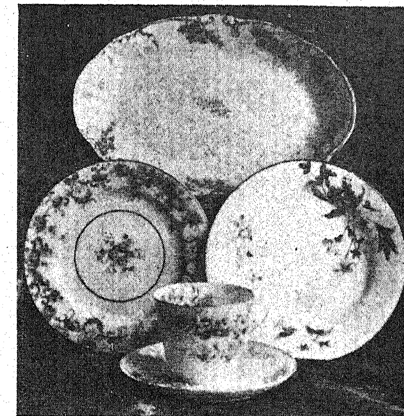
* Coarse ware firm, using Galena only.

The foregoing necessarily includes only those manufacturers who had advanced so far as to be able and willing to publicly give an undertaking and legally bind themselves to do certain things. Many others, no doubt, are slowly endeavouring to qualify in a similar way, and so avail themselves of the advantages offered.

All these improved means necessarily tell upon the health of the operatives concerned, and the results demonstrate the value of greater care in manufacture.

One of the first of Staffordshire earthenware makers who adopted the use of leadless glazes throughout the whole of their works did so by means of formula discovered in the course of the series of experiments recorded in *Researches on Leadless Glazes*; and the firm in question have, since about

March 1899, uninterruptedly continued to manufacture, exclusively, leadless glazed Staffordshire wares to the value of between £12,000 and £15,000 annually, in which underglaze colours are more satisfactorily developed, and inherent good-wearing qualities manifested, than when similar wares were being made by means of ordinary plumbic glaze — moreover, at a less cost, and with evident benefit to their operatives.



W.F.M.] [*Photo.*

FIG. 3.—Leadless glazed china and earthenware.

Several other very large firms have also made considerable commercial use of somewhat similar leadless glaze recipes for the glazing of a portion of their productions. This encouraging experience in the matter of general earthenware and china gives the author great confidence in submitting these, for the most part, newly discovered formulæ for easily fusible non-plumbic glazes for decorative faience.

Arbitration Proceedings, November 1901.—The evidence given during the arbitration at Stoke-upon-Trent in November 1901, between the Home Office and the United Associations of Glazed Pottery and Tile Manufacturers, forms no proof of impracticability of leadless glazes; not a single specialist in, nor exclusive maker of, or advocate of, leadless glazed Staffordshire wares having been heard.

This battle-royal, in fact, was not fought over the question of plumbic *versus* non-plumbic glazes, but merely over the question of the commercial practicability of certain fused compounds, all of which contained a considerable proportion of compounds of lead: it was, in short, except for discussion upon minor matters about which very little difference of opinion existed between the contending parties, an arbitration upon fritted lead glazes *versus* unfritted lead glazes. The principal Government witness, however, proved unable to maintain the position the Home Office desired to establish; and the settlement of the contentious portions was eventually adjourned for eighteen months. It would have been absurd to coerce manufacturers to use particular compositions in their processes, even though the proposed compositions were of a less harmful nature, until such particular compositions had been demonstrated to be commercially practicable.

Lord Henry James and the arbitrators undoubtedly were at that time favourably impressed by the gratifying decrease in notifications of cases of plumbism among pottery operatives, and justly considered it a tribute to the

advantages arising from the greater precautions, self-imposed or compulsory, already practised both by employers and the employed. These precautions being largely a consequence of previous action by the Home Office, under pressure of public opinion, are to that extent a vindication of the efforts of the Home Office, and such results should have saved our governing authority much of the criticism inconsiderately heaped upon it. For even if, in their laudable desire to permanently stamp out a preventable disease, the Home Office unsuccessfully sought to burden the ceramic industry with rules of a too stringent type, this exhibition of excessive zeal cannot be justly stigmatised as a great fault, because, firstly, they submitted to arbitration, and secondly, they were influenced by very strong assertions on the part of those concerned.

For instance, their scientific adviser had said, "It must be clearly understood that complete immunity from lead-poisoning can never be obtained so long as lead compounds continue to be used." And again, "Are lead compounds actually necessary to the potter?—I unhesitatingly reply that as regards glazes they are not. Leadless glazes of sufficient brilliancy, covering power, and durability, and adapted to all kinds of table, domestic, and sanitary ware, are now within the reach of the manufacturer . . . . if the public insisted on being supplied with leadless glazed ware, its demands would be met." (*Royal Institution*, 4th May 1900, p. 12.)

The United Associations of Manufacturers had admitted that "We believe the time has come when the use of raw lead in glazes may be prohibited." (*Brown Book*, p. 5). And Mr. W. Burton, F.C.S., had written, "Could leadless glazes be discovered which were applicable to the conditions of what is known as the general earthenware trade, an immense stride would have been taken towards absolutely ridding our industry of the slightest risks of plumbism." (*The Use of Lead Compounds in Pottery*, p. 39.)

Manufacturers' Opinions.—Glancing at prominent events which have occurred since the arbitration of 1901, at a complimentary banquet on 18th December 1901, inaugurated by the associations of pottery and tile manufacturers to mark their appreciation of the services rendered by Mr. Rawdon Smith, Major Bernard Moore, and Mr. William Burton, F.C.S., Mr. Burton is reported to have said, among other things:—"Lead in any form was a dangerous substance to handle. They could not get out of that, and they should therefore take these two precautions; first, to see that the amount of lead they used in their glazes was as small as was possibly compatible with the results they must obtain on their wares. He realised to the full that every manufacturer must produce the very best he was capable of; and he knew perfectly well that there were certain manufacturers in this country who made wares of such excellence and such quality that nothing less than raw lead under their conditions would produce what they desired. All he had to

say to such gentlemen was: then, for their own sakes, and for the sakes of their trade, make their conditions of life and work as good as they could be. There were others who could reduce the quantity of lead they used in their glazes, or reduce to a certain extent the standard of solubility. To them he said it was their very plain, simple duty to make the reduction." (*Staffordshire Sentinel*, 19th December 1901.)

If Mr. W. Burton had definitely specified the particular class of ware, in the glaze of which he asserts that *raw lead* is, under certain conditions, essential, it would then have been possible to discuss the evidence pro and con: in the absence of such particularization, we can only draw attention to the encomiums lavished by Mr. Burton and other eminent savants upon mediæval Persian wares; and their own equally emphatic complaint of the dangers of lead glazed wares, both to the operatives who make them and, in certain classes of ware, to the consumers who use them.

Mr. Burton's sterling advice to other manufacturers whom, he asserts, "could reduce the quantity of lead they used in their glaze," should be heartily approved and endorsed, and it is to be hoped that manufacturers promptly took the course their distinguished expert fellow-manufacturer so publicly and fearlessly pronounced to be "their very plain, simple duty."

At the same notable banquet, Major Bernard Moore, another manufacturer who had taken a prominent part in the negotiations between the Potters' Associations and the Home Office, remarked that:—" There were men, finally, who thought that a brother manufacturer who used leadless glazes, or a glaze of low solubility, or even one who fritted his lead, was a kind of traitor. He cared nothing for the opinion of such a man. He recalled the words of Lord James, who hoped the manufacturers would do their best to make the world around them a better world and to improve the condition of their workers. If he (the speaker) refrained to do what he could, he would stand there ashamed. If ever restrictive legislation of an injurious character were imposed upon the trade, it would rest at the doors of those who sat still and did nothing to improve their methods." (*Sentinel*, 19th December 1901.)

Thus, admittedly, there is a field for judicious interference by the Home Office in the interests of humanity. And if the Home Office find it imperative to frame and to enforce rules to meet such deplorable contingencies as Mr. Moore so plainly indicated, then let Major Moore himself, who enunciated, and the hundred manufacturers who thereupon approved his emphatic disavowal of the class he referred to, stand by his words and support the Home Office in its benign endeavours.

Outsiders.—Derogatory comment has frequently been made upon the misguided (?) interference of well-meaning "outsiders": yet, curiously enough, the history of ceramic art furnishes very many instances of potential improvements by outsiders. For example, the discovery and practical use of Cornish

china clay and china stone for bodies and glazes; of plaster of Paris for moulds; of transfer printing upon pottery ware; of salt glazing; of the use of calcined flints; of the invention of the filter-press for clay preparation; of stilt-making machines; of cobalt oxide as it is now obtained for the industry; of liquid gold; of ruby lustre; and last, but not least, perhaps the dust-tile press itself: really, upon reflection, it is seriously to be doubted whether the complacent, conservative, and self-esteemed "insider" has anything better to record; and by-the-bye were not Luca della Robbia, and Bernard Palissy, and Boettgher, and Elers, and Thomas Minton "outsiders"?

Even in this particular question of lead-poisoning which has been smouldering in potting circles since Josiah Wedgwood began to make his famous Queensware (see *Letters of Josiah Wedgwood to Bentley*, vol. ii. pp. 43 to 48), and since the days of Simeon Shaw, are we to suppose that in the absence of outside agitation, and of action by the Home Office, the cases of plumbism in potteries would have receded as they have, from 432 in 1896 to 106 in 1901, and 87 in 1902? reductions equivalent to 15,000 cases within half a century. Such a supposition is hardly a tenable one, in face of the remarkable coincidence of the work of the Hanley Labour Church Committee, in December 1897, and subsequently, with the formation of a public opinion on the question, and its culmination in a demand for public inquiry. Indeed, Mr. Laurence Wedgwood stated in evidence before the adjourned arbitration that "he attributed the freedom from lead-poisoning enjoyed by his firm to a large extent to the rules of 1898." (*Staffordshire Sentinel*, 1st July 1903.)

The Commercial Aspect.—Again, with equal inaccuracy and injustice, articles have been published in the Press conveying the innuendo that commercial failures among potters, if not wholesale bankruptcy, was almost certain to accompany the general adoption of leadless glazes. Now, of what the future may have in store we know nothing, but we know something of the recent past, and that proves beyond question that not a few firms who have used ordinary lead glazes have appeared in the Bankruptcy Court. A comparison of the *Pottery Gazette* directory of 1890 with that of 1904 reveals the fact that more than sixty failures may be counted, to say nothing of those who have risen, shone, and declined, in the interim.

Not only so, for it is now becoming fashionable, or at least not unusual, to advocate the manufacture of hard porcelain as a means of saving our chinaware trade. Refer to Mr. A. F. Wenger's speech at the English China Manufacturers' Association meeting at Longton on 19th February 1903, wherein he clearly suggested the manufacture of leadless glazed wares as a commercial expedient to conserve the staple of the Longton chinamakers' trade. In commenting upon this speech, the Staffordshire correspondent of the *Pottery Gazette* remarked, "That is a suggestion worth considering. It has been more than once suggested in these columns, not, indeed, that the

manufacture of bone china should be discarded, but that some enterprising potter should see what could be done with the manufacture of hard porcelain. It is a beautiful product when well made and fired, and *its greater durability* in contrast with much of the cheaper qualities of bone china is a thing not to be denied." (*Pottery Gazette*, March 1903, p. 286.)

If one thing is more certain and evident than another it is that leadless glazed hard porcelain wares are gaining a well-merited public esteem; and that a silent process of irresistible evolution is going on, under the influence of public opinion and self-interest, which must ultimately affect the question of plumbism in potteries almost as powerfully as any changes enacted by Parliament. Previous to the agitation in favour of leadless glazes these ceramic compositions certainly had not received, in Great Britain, the attention they deserved from manufacturers, even on purely economical grounds, although several English potters had made careful inquiry on the Continent, and attempts at home, in the direction of hard porcelain.

Returning to the subject, in the *Pottery Gazette* of April 1903 the same correspondent remarks, "The question of all others which needs to be decided is that of bone *versus* felspar china. Is the latter, for cheap and useful lines, ousting the former from its place? That the cheapest Longton china is not a very choice production, either from a utilitarian or æsthetic point of view, is undeniable. Cheap bone ash and inferior china clay and stone produce a china of very small value from any point of view, and felspar china of almost any description has the advantage of superior wearing qualities. . . ." "It is a significant fact that the United States imports vastly more of Limoges and continental china generally than of our china, and that such china as is at present manufactured on the new continent is of the felspar variety." (*Pottery Gazette*, April 1903, p. 393.) Then, in the May issue, he reports that Mr. Harold Plant, son of one of the largest china manufacturers of Longton, had very recently said, "They were on the verge of a revolution in the china trade," and had "either got to adapt themselves to new methods, or to go under and let Germany and America go to the top." (*Pottery Gazette*, May 1903, p. 497.)

In the *Staffordshire Sentinel* of 29th June 1903 it is asserted that foreign earthenware and china is being imported into the United Kingdom at the rate of £1,000,000 per annum, and this before any regulations as to composition of the glazes had been settled; while Rules 1 and 2 stood adjourned, and "lead" still dominant and free. Therefore, clearly, "lead" is not such a complete safeguard of manufacturers' interests as has been assumed, nor a bulwark against foreign competition. Indeed, it would appear almost that the much abused leadless glazes may yet be the most powerful means of saving the Longton china trade. And as to profit, the *Pottery Gazette*, July 1903, p. 696, refers to German manufacturers' profits as 12·98 per cent.

These things, perhaps, are rather aside of the subject of decorative tiles, but they are legitimate citations in the advocacy of non-poisonous glazes. Nor is the analogy overstrained, for, on the one hand, there is a remarkable example of hard-porcelain tiles in the Hanley Museum, in the form of a screen of Chinese tiles; and, on the other hand, it is well known that constructional faience for exterior work has met a powerful competitor in the form of polychrome enamelled stonewares of a leadless type. Of these Mr. Burton has said:—"On the Continent, however, and to some extent at home, a newer kind of stoneware is coming to the front, in which there is greater range of colour, texture, and glaze quality than is possible with salt glaze. In France, this movement is most strongly marked; and in addition to such well-known firms as Emile Muller, Bigot, etc., we find artist potters like Delaherche, Lachenal, and Delpayrat producing most artistic work in *grès* or stoneware . . . . the body is hard and vitreous, and, in most cases, body and glaze are produced at one fire, and that a high one. The glaze, however, is no longer salt-glaze, but in most cases is produced by simply softening some native felspathic mineral, similar to our Cornish stone, by added fluxes. With the hard fire necessary to melt such a glaze, and the fine colour-developing qualities inherent in felspathic materials, the results are often singularly soft and harmonious; and as the range of colour obtainable is very great, from the softest grey blues to *rouge flambé*, the newer stonewares will undoubtedly form an important addition to the long list of pottery species. On the Continent, and especially in France, Germany, and Hungary, these stonewares are rapidly coming into use for the exterior decoration of buildings, a service for which their hardness and durability admirably fits them. Perhaps in another half-century, English architects will wake up to this fact, and give the English potter a chance in the same direction." (*Journal Society of Arts*, 22nd February 1901, p. 217.)

Oven Fumes.—Another "bogey" used in connection with the public discussion upon leadless glazes is that of "borrowed plumes" from the oven fumes, the influence of oven fumes upon leadless glazes being discussed in such a manner as to convey to the general public the impression that the good appearance of leadless glazed wares arises from the effect of these undesirable gases.

Now if oven fumes, as existing outside the saggars, are beneficial, why do manufacturers lute and glaze the saggars and muffles, and take every practicable means of excluding such fumes? All that can justly be taken into consideration is the effect of fumes from the saggar wash, acting separately within each saggar. To test the effect of this, specimens dipped in lead-free glazes have been fired in saggars washed with lead-free glaze, and placed in the oven between other saggars similarly washed, and the results were perfectly satisfactory. Trials dipped half in lead glaze and half in leadless glaze,

prepared in duplicate and fired, one series in saggars washed with lead-free glaze and the other in saggars washed with ordinary lead saggar-wash, convincingly demonstrated the fallacy of the "borrowed plumes" bogey. Subsequently, duplicate series of "majolica" leadless glazed decorative tiles were fired, one series in a leadless glaze washed box, and the other in a lead glaze washed box, and certainly the trials showed that whatever advantage in appearance there was between the two, gravitated towards the lead-free series.

During a long course of experiment the author cannot recollect a single instance in which a wrongly compounded lead-free glaze has been improved so as to appear good by any influence of saggar-wash fumes; and he is persuaded that such effect is practically a negligible quantity compared with the influence for better or for worse of the glaze itself.

Looking backward.—To understand the true state of affairs from a technical point of view prior to the recent public agitation against lead poisoning and its causes, it is necessary to look back a little. The following excerpt from the expert evidence given before the Potteries Committee of Inquiry in 1893 will enlighten us:—"Mr. T. W. Harrison, colour maker, Hanley, and Mr. Harrison, jun., potters' chemist, Hanley, attended, and the former, in reply to questions, said:—The proportion in which raw white lead enters into glazes varies considerably—in white glaze from 15 per cent. to 30 per cent. Good glaze should not contain more than 15 per cent. of raw lead. In yellow or 'cane' ware, about 30 per cent. is used; in a soft glaze for common 'Rockingham' teapots, as much as 40 per cent. For practical purposes, nearly all the lead is used raw. Vinegar or soda will set free the lead in very soft glazes containing a large proportion of raw lead. These soft glazes are not only injurious to the pottery workers, but also to the public. Majolica ware is covered with a coloured glaze, and in this the proportion of raw lead is from 25 per cent. to 40 per cent. by weight. Considers it more injurious to workers than any other, and has known of more cases of lead-poisoning amongst majolica paintresses than amongst any other workers. . . . As to the practicability of using fritted lead he does not entertain any doubt, and produces specimens of ware dipped in a glaze in which all the lead has been fritted, also a plate, half of which has been dipped in a fritted glaze, and the other half in a raw lead glaze, and there is no appreciable difference. . . . Fritted lead is practicable for majolica and other colours, but it would be more costly, and it wears out the frit kiln very fast. As a manufacturer of glazes, he would not be afraid of a law prohibiting the sale of glaze containing raw lead." (*Report on Conditions of Labour in Potteries*, 1893, p. 18.)

The inference from the foregoing is that the manufacture of decorative tiles has hitherto been effected by means of a hazardous proportion of lead compounds in the glazes, and this is confirmed by the series of chemical

analyses of such glazes by Professors Thorpe and Oliver, in which the use of from 49 to 57 per cent. of lead oxide is proved.

It would seem that, of all the branches of pottery manufacture, the decorative tile industry has employed the greatest proportion of lead salts in the glazes; if, then, this new series of non-plumbic formulæ or recipes render practicable the manufacture of these goods without the aid of lead, just as the writer's former publication assisted in the production of general earthenware and chinaware without lead, then the whole range of Staffordshire ceramic manufactures may be considered possible without the use of lead compounds.

Obstacles.—Whether the demonstration of such a portentous fact in a few instances will be the means of an early and general abandonment of lead is another question. Many interlocking interests are at stake. One pottery manufacturer may have thousands of pounds invested in lead works; another may be resident local representative of makers of white lead; others may have, in the recent discussions, practically staked their reputation as expert ceramists against leadless glazes; inertia, fear, prejudice will do the rest; and so a host of enemies range themselves almost unconsciously and unintentionally athwart the path of lead-free glazes for Staffordshire products, and in actual practice it is so convenient to charge against any innovation all the everyday troubles that arise from time to time—troubles that have been repeatedly confessed to in the case of ordinary lead-glaze wares.

"Disaster after disaster," we are told, crossed the path of Josiah Wedgwood, as he persevered in the perfection of his now famous Queen's ware. "Even long experience cannot enable us to foresee all possible accidents," said M. Solon, after practising his special art of *Pâté-sur-Pâte* for thirty-five years. "Even when the conditions are most closely observed, the results will show unexpected variation," wrote De Morgan. "Every potter knows by bitter experience how easy it is to spoil certain kinds of glaze by inattention during the firing process." W. Burton, F.C.S., *Journal Soc. Arts*, 22nd Feb. 1901, p. 216.

And more: the special correspondent of *The Pottery Gazette*, referring to ordinary lead-glazed wares, confessed that dippers, placers, and other workers know from "practical experience what it is for ware by the hundred dozen to come out of the oven bad." (*Pottery Gazette*, Dec. 1901.)

Is it, then, unreasonable to crave a modicum of forbearance and impartial criticism of lead-free glazes? If after a hundred and thirty years of consecutive and cumulative experience, *picking out the good* is still necessary with lead-glazed wares, why deny a few crumbs of just consideration to wares glazed with leadless glazes?

But we know that "nolens volens" action even on the part of a friendly employer is almost impossible on his own factory. We therefore foresee a

great group of adverse circumstances that inevitably form obstacles to the rapid adoption of leadless glazes. Meanwhile, we ask that those who still discredit them will reserve their criticism, or else personally test the formulæ, for non-representation is better than mis-representation.

First attempts at the practical solution of all great and difficult problems are usually accompanied by initial disappointments. The massive chains now forming Clifton Suspension Bridge are said to have lain idle many years awaiting funds and enterprise. In like manner, leadless glazes for decorative tiles and faience when once discovered must nevertheless bide their time, until those who possess the power and opportunity put them into use.

Public Opinion.—Speaking in the House of Commons on 25th June 1903, H. J. Tennant, Esq., M.P., remarked that "the example set by that House, by the House of Lords, and by public departments, had resulted in this remarkable circumstance,—that they were able to purchase in the open market leadless glazed articles every bit as good in quality, and as cheap, if not cheaper in price, as articles made with lead glaze." (*Pottery Gazette*, July 1903, p. 718.) That intelligent public opinion is strongly in favour of lead-free glazes cannot be denied, and they are labouring under a very misleading delusion who suppose that when an architect reads of the sickness or death of a dipper, a placer, or a majolica paintress from lead-poisoning—even though the notified cases have been reduced to less than a hundred per annum—he calmly ignores it, or facetiously explains it away.

Paul Waterhouse, Esq., M.A., etc., probably echoed the genuine and general opinion of the profession when he said:—"Many architects who had consciences on the subject of lead-poisoning might have felt that by an extensive use of glazed tiles they might be increasing the modern evil of lead-poisoning. There was, however, another side to an architect's feelings on the subject, namely, that he not only had that difficulty before him, but he had the opportunity of doing a great deal of good in connection with the matter. Those who would take the trouble to make inquiries as to the nature and as to the relative poisonous qualities of the various glazes in different kinds of tiles, would find that the mere fact of inquiring on the subject helped the battle which the Home Office was endeavouring to successfully carry through against careless manufacturers. He could not claim to have been innocent in this matter, nor to have never made use of tiles which were poisonous; but he had made some inquiries on the subject, and it was refreshing to find, not only how much was done by the more enlightened manufacturers in the way of getting rid of harmful glazes, and the substitution of those which were either harmless or less harmful, but also that of recent years some extremely successful experiments had been made in the use of altogether leadless glaze. Not long ago, inquirers would have been

informed by any manufacturer of faience that it was impossible to produce a leadless glaze which had the proper external appearance. That was no longer true. More than one manufacturer was now engaged in producing tiles which were absolutely leadless." (*Journal Society of Arts*, 24th January 1902, p. 168.)

Assuming, then, as we have a perfect right to do, that an equally sympathetic disposition pervades the whole profession, who, as Mr. Waterhouse implies, have considerable power, it is worth remarking that that influence can make itself felt in favour of those manufacturers who are willing to make decorative wares by means of non-plumbic glazes. It therefore behoves those concerned to put their house in order before business is diverted to foreign channels even for home requirements.

The salts of lead are well known to be poisonous: in the United Kingdom, during 1902, in all trades, including house-painters, there were 807 cases of lead-poisoning, and these included 46 deaths. In white-lead, red-lead, and yellow-lead works where potters' requirements among others are prepared, there were in 1902 in the United Kingdom 156 cases, including 1 death. In the china and earthenware industry and litho-transfer works in the United Kingdom, during 1902, there were 88 cases, including 4 deaths. And the number of pottery employees "suspended" in the Hanley, Burslem, Tunstall, and Stoke districts alone during 1902 was 68 (63 females and 5 males), of which 21 were believed to have been permanent—see Government reports—the statistics for 1903 showing a rather greater number of cases.

Lead compounds thus are a nationally recognised danger and an obstacle to the extension of the ceramic industry, because fear and distrust enter the minds of those who would be otherwise willing to make greater use of ceramic products. Remove the obstruction by adopting lead-free glazes, and then architects and others will be perfectly free to follow up the use of ceramic products in architecture to its utmost possibility.

The Adjourned Arbitration.—In due course the adjourned meeting of the arbitration took place on Tuesday and Wednesday, 30th June and 1st July 1903, at the North Stafford Hotel, Stoke-upon-Trent,—Lord James of Hereford presiding in the capacity of umpire, as before.

The object was to consider and discuss the statistics relating to cases of plumbism in potteries which had arisen during the period of the adjournment, and to settle upon some definite course respecting Rules 1, 2, and 6 of the previously proposed Special Rules, which, owing to their contentious character, had been postponed from the previous inquiry for eighteen months.

The proposed rules in question were:—

"No. 1. After 1st July 1901, no material containing lead which has not been fritted shall be used in any of the following places:

"Dipping-house, or dippers' drying-room, or in any of the following processes:

"Ware cleaning after the application of glaze by dipping or other process.

"Glost placing.

"Colour dusting (whether on glaze or under glaze).

"Colour blowing (whether on glaze or under glaze).

"Groundlaying.

"Painting in majolica or other glaze.

"Glaze blowing.

"Litho-transfer making.

"Or in any other place or process in which materials containing lead are used or handled in the dry state (except for the making of fritts) or in the form of spray, or in suspension in liquid other than oil or similar medium. Provided that nothing in this rule shall prevent the use of any ore or chemical compound of lead which, without the admixture of any other material, conforms to the standard of insolubility specified in Rule 2.

"No. 2. After 1st July 1902 no glaze shall be used which yields to a dilute solution of hydrochloric acid more than 2 per cent. of its dry weight of a soluble lead compound calculated as lead monoxide when determined in the manner described below:—A weighed quantity of dried material is to be continuously shaken for one hour, at the common temperature, with 1000 times its weight of an aqueous solution of hydrochloric acid containing 0·25 per cent. of HCl. This solution is thereafter to be allowed to stand for one hour and to be passed through a filter. The lead salt contained in an aliquot portion of the clear filtrate is then to be precipitated as lead sulphide and weighed as lead sulphate.

"No. 6. Every person employed in a place or process included in Rule 1, or in the process of china scouring, shall be examined once in each calendar month by the certifying surgeon for the district. The certifying surgeon may order, by signed certificate in the register, the suspension of any person from employment in any place or process included in Rule 1, or in the process of china scouring; and no person after such suspension shall be allowed to work in any place or process included in Rule 1, or in the process of china scouring, without a certificate of fitness from the certifying surgeon entered in the register."

Mr. J. Roskill, K.C., submitted evidence showing that the number of cases of Plumbism in Potteries during 1903, up to date, was the same as during a similar period of 1902, and he claimed that upon the whole, "the figures the Home Office had put forward clearly showed that the prevalence of lead-poisoning amongst the women and children was as bad in 1903 as it was in 1902—perhaps worse. He thought a fair deduction from that fact was that

inspection was not sufficient . . . ," "inspection alone had proved insufficient in the case of women and children, and that it was proper to infer that it would prove equally insufficient in the case of men."

At another stage he remarked that "with regard to Rule 1, the Home Office did not lay much stress on the question of fritting, because it had arrived at the conclusion that fritting, if negligently or unintelligently carried on, offered no safeguard on the question of low solubility." He nevertheless asserted—in reply to an inquiry by Lord James for a suggestion as to a low solubility rule—that "the Home Office proposition was and still remained 2 per cent."

He criticised the provisions of the Potters' Insurance Scheme as "ridiculously insufficient," and stated that it did not satisfy the Home Office; and in conclusion he said, "There was nobody at present in that room, he was certain, who was not alive to the pressing importance of that question. The Home Office were satisfied if these Rules were passed that at last something would be done final in its nature which would preserve the health of the workers of this district, and render safe one of the earliest and most beautiful industries of civilisation." (*Sentinel*, 1st July 1903.)

Mr. Fletcher Moulton, K.C., with conspicuous ability, pointed out that "since July 1901, *i.e.* two years, no case had been found amongst the boys engaged, and since September 1901 no case had been found among the girls engaged"; but he admitted that "In consequence of the new rules a larger number of women were certainly employed in the dipping houses . . . . instead of boys."

He claimed that "The position he took up as representing the manufacturers . . . . was perfectly reconcilable to the greatest possible care of the health and the well-being of the operatives. His clients objected to no particular rule regulating the apparatus used, the precautions to be taken with regard to cleanliness, and the use of fans. . . . . They also had no objection to—in fact they themselves had tried, as far as possible, to introduce a system of regular inspection of adult males, and they were also willing to co-operate with and to follow the advice of the Home Office and his Lordship with regard to insurance . . . . but they believed it was absolutely impossible, without injuring the industry and producing suffering infinitely greater than that already existing, to interfere with the discretion of the manufacturers in the selection of the materials used and the form in which they were used . . . . any attempt to interfere with the way in which they were to deal with the lead would be disastrous to the most important and most advanced part of the industry. . . . ." He admitted that "Plumbism is very, very common among house painters," yet, he said, "No one ever thought of forbidding a man to paint a board with white lead," and he premised this by saying that ". . . . He could not help feeling that if there were people to

be trusted with the use of white lead, it was the manufacturers who had to act under those rules and who were willing to have that insurance scheme."

With regard to Rule 2, he said, "There was a unanimous feeling among his clients that any action which treated Rule 2 as being a practical rule would be disingenuous on their part, and they could not in any way consent or do anything but resist, so far as they had the power, a rule of the nature of regulating the solubility." In discussing a question by the learned umpire, addressed in the first instance to Mr. W. Burton, F.C.S., as to what objection he would have to any rule, provided there were a provision that it should be held not to apply to every factory the owner of which had joined the association in the agreed terms, and which had been carefully and properly conducted, Mr. Fletcher Moulton observed, amongst other things, "If Rule 2 were passed, the Home Office would very likely think that all they were doing was simply controlling the manufacture, whereas the whole trade knew it would be simply destructive to the whole trade." (*Sentinel*, 1st July 1903.)

But the most instructive evidence at this adjourned inquiry was that of Mr. William Burton, F.C.S., and he is deserving of the highest praise for his courageous admission of the practicability of leadless glazes. After all that has been poured out of uninformed minds against leadless glazes, it was an intense pleasure to peruse Mr. Burton's evidence. And be it remembered, he claims that "without boasting, he could say that they had in their business a greater amount of scientific knowledge than probably any other firm in the country." (*Sentinel*, 1st July 1903.)

In the first place, respecting Rule 6, he is reported to have stated "That every manufacturer believed as strongly as he did in the advantage of Rule 6, and that the great majority of manufacturers would be willing to enter into an insurance scheme on the lines of the Workmen's Compensation Act," and he added that "he thought they ought to be compelled to do so." (*Sentinel*, 1st July 1903.)

"Mr. Burton went on to say that he had for a long time considered the possibility of making restrictions as to the fritts and the solubility of the lead, and that he had found that *it was possible for certain manufacturers to use leadless glazes. There were a few manufacturers who could use leadless glazes entirely, and they ought to be encouraged to do so.*" . . . . "Mr. Burton proceeded to say that there were other manufacturers who partly used leadless glazes. *He himself had used it successfully for the cheapest and commonest class of his work*, but for the great bulk of his output—the better-class work—he could not use it at all, although it might be put on the same body and fired in the same ovens." (*Ibid.*)

"Mr. Burton handed to the arbitrators and umpire samples of tiles produced with leadless glazes, and said that if he were asked to supply a quantity of white tiles with leadless glaze he could not supply them unless the purchaser

agreed to take his selection. In another department he had used fritted lead quite successfully. He had also tried lead of low solubility—under 2 per cent.—quite successfully, but with the difference that while his ordinarily glazed ware was fired in all parts of the ovens, and had to take the chance of hard fire and poor places, and he got 94 per cent. of best goods, the ware glazed with 2 per cent. soluble lead had to be fired in the best parts of the kiln with great care, and he got 86 per cent. best goods. Of the ware glazed with leadless glaze only 70 per cent. was best goods. The ordinary glazes, although fritted, were soluble up to 40 per cent., and in the purview of that inquiry they might be regarded as equivalent to raw lead. The ware coated with leadless glaze or with low solubility glaze always had preferential treatment in the oven. He expressed the opinion that the great reduction in the number of cases of plumbism among majolica paintresses—from 10 per cent. in 1898 to about 0·7 at the present time—was due firstly to the monthly medical examination, and secondly to the exercise of greater care by the workers themselves. It could not be contended that the decrease had been brought about either by the use of fans or by the use of glazes of less solubility. Fans were not required in that process, and it was impossible to deal with the solubility of the glaze used in majolica work. He employed more majolica paintresses than anyone in North Staffordshire. . . . . There had undoubtedly been efforts made among the trade to increase the use of fritted lead and of glazes of low solubility. He himself had endeavoured to find a good standard of solubility that would cover the whole of his works, but such a standard would have to be 50 or 60 per cent. . . . ." Mr. Burton also referred to the Jet and Rockingham trade as a proof that "white lead could be handled with impunity and without fritting." (*Ibid.*)

"Asked by Mr Roskill whether he still believed in fritting, the witness said that personally he fritted every ounce of his lead . . . ," but he added, "Fritting . . . . did not do away with the difficulty. . . . ." "He thought the operation of the new rules would tend to reduce lead poisoning"; but when questioned as to the acceptability of a rule relating to solubility, but subject to a provision that it should not apply to those factories the owners of which joined the association and accepted the terms to be agreed as to compensation, and could prove that the work was carefully and properly conducted, he answered, "It is not a question of sentiment. It is a question of this kind, that, in order to arrive at that, I am to allow to be put down in the rules as a possible thing—as a thing which can be worked at all—something which my experience has proved to me is impossible." (*Sentinel*, 1st July 1903.)

The assertions from such an authoritative source that "*there were a few manufacturers who could use leadless glazes entirely*," and that "*he himself had used it successfully for the cheapest and commonest class of his work*," would probably have electrified the arbitration of 1901, and have caused potential

changes *then*: but, coming at this comparatively late hour, they exercise less independent force, because the practicability of leadless glazes for many purposes was already demonstrated by the nineteen certificates of exemption granted under Rule 22.

"Without boasting," then, it seems only fair to remind all whom it may concern that a statement as to the practicability of leadless glazes was at the service of the industry in 1898, namely, that "Fair leadless glazes, answering reasonable expectations and requirements, are not only desirable, but are an accomplished fact" (*Researches on Leadless Glazes*, p. 28); and if the source was not so authoritative, it was equally true. That is nearly six years ago, and since then very much more has been learned about the possibilities and practicabilities and durabilities of leadless glazes; and so far as these have come under the observation of the author, all this newly acquired knowledge is herein submitted to the industry and the public, with a view to assisting in lessening plumbism in potteries and glazed tile factories.

Not only so, but the recent determination of the Home Office to withdraw from its position with regard to the proposed Rule 1 and all indiscriminate fritting of the lead compounds was unmistakably anticipated on pages 2, 3 and 4 of *Researches on Leadless Glazes*, published in 1898.

As to comparison of specimens of leadless glazed tiles with lead glazed tiles, shown to the arbitrators, the writer respectfully submits that these should not be taken as correctly presenting the case for lead-free glazes, because they were not shown by advocates of the use of exclusively leadless glazes. Could not less excellent specimens of lead-glazed tiles have been submitted, and better ones of leadless glazed tiles? and in that way the comparison very greatly modified?

But however that may be, leadless glaze advocates may take consolation from the manufacturers' evidence that leadless glazed ware, in *whole ovenfuls, exclusively*, is in certain cases practicable.

It then becomes only a question of quality, which necessarily is a matter for the jury of public opinion, and may be left to the exigencies of competition.

The public have now—publicly, in evidence—been most authoritatively informed that they can be supplied with leadless glazed tiles: the onus is thus laid upon the public: if they want to buy tiles glazed with non-plumbic glazes they can have them.

In concluding the proceedings of the adjourned arbitration, Lord James observed: "I purpose giving my decision in writing within a short time, certainly within two or three weeks. That decision in writing will convey all, I think, ought to be conveyed to the public on the subject. But there are one or two direct matters, apart from the whole extent of that decision, which I must mention. Although I am giving no decision here, as I say, orally, the train of my opinion has probably been more or less conveyed to those who

have been in this room—necessarily conveyed by the questions I have felt it my duty to put, and by the statement I made yesterday morning; and, therefore, it is not disclosing at all what may be in my mind if I say that it may be that it will be necessary to frame a schedule, an agreement with a schedule—rather regulation—a regulation to be placed in the schedule, controlling an assurance scheme of compensation in the case of illness from lead-poisoning. That is a matter of detail, and it is a matter which so closely concerns the material interests both of the employer and employed, that great care ought to be taken in framing it, if it is framed at all. . . . . I do not wish to do anything hostile in a matter of such importance; but considering fully all I have heard, I do wish, however, to say that I am rendered more hopeful by what has occurred in the past in the lessening of the amount of disease that now exists. I am also rendered more hopeful by what has occurred in this room. I do not think I have heard either from the employers, or from the Home Office representatives, or from the operatives, one word which does not tend, I think, to display a desire to bring about an arrangement, a determination that shall bring about a lessening of this disease. . . . . Now, gentlemen, all I will promise you is that on this day twelve months—on 1st July 1904—I will send to the Home Office to know the result that has been accomplished by our labours, and I am very confident that, without injuring the trade in the way it is carried on, we shall have produced results that will have brought about a lessening of this disease, almost to a nominal extent. . . . . I hope my confidence will not be so without foundation, because, although I have some fear of it, I assure you my mind is full of good wishes towards the great and beneficial trade, and also towards the workmen who are engaged in supporting that industry." (*Sentinel*, 1st July 1903.)

The Award.—The text of the award, which was signed by Lord Henry James of Hereford in December 1903, was not published in precisely the terms in which it was signed; but the results of the award were embodied in a series of amended special rules prepared in pursuance of the award.

These amended rules we are permitted by Dr. Whitelegge, Chief Inspector of Factories, to publish in full, and they will be found reprinted at the end of this volume as an appendix (Appendix A).

The necessity for such safeguards as it provides clearly demonstrates the seriousness and reality of the problem and the desirability of ridding the industry as soon as possible from an ingredient that renders necessary such an organised effort to mitigate its pernicious effects.

Conclusions.—Finally, it may be remarked that in summarising the foregoing, three points should be kept in view:—

Firstly, that notwithstanding the great decrease of notifications of plumbism in potteries between 1898 and 1903, if we except house painters, then white lead works, whence potters obtain their supplies of prepared lead compounds,

together with the ceramic industry, still, as a whole, numerically head the list of notified cases in the annual returns, standing in violent contrast with other trades.

DISEASES OF OCCUPATIONS IN FACTORIES AND WORKSHOPS.

TABLE showing the number of cases of lead, mercurial, phosphorous, and arsenic poisoning and of anthrax reported to the Home Office under the Factory and Workshop Act, during the under-mentioned periods. Compiled from official figures published by the *Labour Gazette* (*Sentinel*, January 1903-4). (Cases include all attacks, fatal or otherwise, reported to the Home Office.)

Disease and Industry.	Cases.			Deaths.		
	Year ended December			Year ended December		
	1901.	1902.	1903.	1901.	1902.	1903.
LEAD POISONING—						
Smelting of metals,	54	28	37	3	...	2
Brass works,	6	5	15	1	...	...
Sheet lead and lead piping,	17	12	11	...	...	...
Plumbing and soldering,	25	23	26	...	1	...
Printing,	23	19	13	1	...	2
File cutting,	46	27	24	7	1	2
Tinning and enamelling of iron hollow ware,	10	11	14	...	...	...
White lead works,	189	143	109	7	1	2
Red and yellow lead works,	14	13	6	...	...	...
China and earthenware,	106	87	97	5	4	3
Litho-transfer works,	7	2	3	...	...	...
Glass cutting and polishing,	11	8	4	3	2	...
Enamelling of iron plates,	9	3	4	...	1	...
Electrical accumulator works,	49	16	28	1	1	...
Paint and colour works,	56	46	39	...	...	1
Coachmaking,	6	63	74	4	1	5
Shipbuilding,	25	15	24	1	1	1
Paint used in other industries,	61	44	46	...	1	1
Other industries,	89	64	40	1	...	...
	863	629	614	34	14	19
HOUSE PAINTERS AND PLUMBERS, Total,	169	179	201	41	32	39
MERCURIAL POISONING, Total,	18	8	8	...	...	...
PHOSPHORUS POISONING, Total,	4	1	...	...	2	...
ARSENIC POISONING, Total,	12	5	5	1	...	...
ANTHRAX, Total,	39	38	47	9	9	11

Secondly, that the cases (47) among females in china and earthenware manufacture were numerically equal to those of all other trades combined during 1902.

Thirdly, that a slight recrudescence occurred in the month of July 1903, 14 cases having been notified as compared with only 4 cases in July 1902, and that affected the annual returns to a like extent; these show 97 notified cases of lead-poisoning in the china and earthenware trades during the year 1903 as compared with 87 during 1902, although the deaths during 1903 were one less than in 1902.

Then, in January 1904, china and earthenware works again show a conspicuous recrudescence as compared with other industries, 15 cases being notified in January 1904 against 8 cases in January 1903.

Therefore, though it may be granted that, nationally speaking, there are very many more urgent fields for reform, and many greater social problems awaiting solution in which more lives are at stake, this question of plumbism, at least, is one channel wherein it can be clearly demonstrated that preventable disease awaits prevention, and so furnishes the "Raison d'être" of this volume.

CHAPTER II.

HISTORICAL REVIEW

OF DECORATIVE TILEWORK AND CHROMO-FAIENCE.

CONTENTS.—Service of the potter's art in history—Babylonian and Assyrian—Egyptian—Grecian—Roman—Romano-British—Persian—Syrian—Rhodian—Saracenic—Turkish—Hispano-Moresque—Indian—Chinese—English Mediæval—Italian Mediæval and Renaissance—German Renaissance—French Mediæval and Renaissance—Delft.

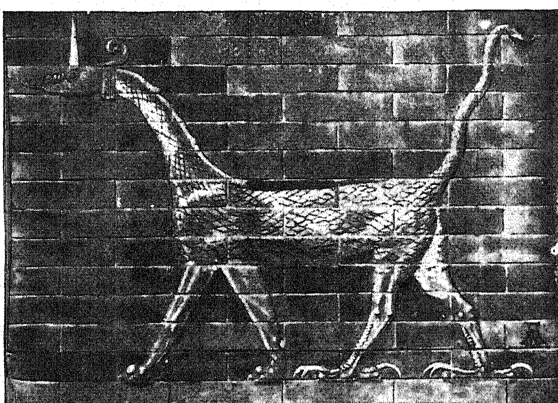


FIG. 4.—Enamelled brickwork from Babylon—"The Dragon of Babylon." (*By permission of Williams & Norgate, London.*)

BEFORE entering upon the *technique* of decorative ceramic products, some historical notice of their use in the past seems desirable, irrespective of the chemical nature of the glazes or enamels upon them.

Fortunately or not, we cannot begin at the beginning, for the beginning of the "Tigelwyrtena craft," as our Saxon forefathers styled it, is lost in the mists of antiquity.

Nevertheless, the story of this branch of art, even though imperfectly told, may be interesting, for historical records not infrequently are a means of rescuing from oblivion and restoring to utility neglected or long-forgotten arts,—salvage so to speak, from "the wrecks of another world."

If less exciting, the peaceful history of industry and art is at least more elevating than much of that dispensed in text-books or proclaimed by sculptured rocks—history of the conquests and defeats of armies, the rise and fall of empires—often little more than one long horrible revelation of the greed, the vanity, the duplicity, and the cruelty of man.

In countries where marble and stone are abundant and clay deposits rare the use of ceramic products in building construction is, usually, subordinate; its highest development mostly coinciding with the occurrence of suitable materials, favourable environment, artistic propensities, and possibly some more or less beneficent tyranny.

Modified by these and other less manifest influences, the ornamental-tile maker's craft has flitted fitfully hither and thither in the wake of early civilization, leaving indelible traces where once the Babylonian, Egyptian, Persian, Arab, Mongol, Moor, or monk held sway.

It has been said, "the useful arts are the offspring of necessity"; perhaps it would be equally true to assert that they are more easily learned than invented: Asiatic migrates to Egypt and teaches the Aboriginal the arts of Asia: Greek, learning in Egypt, can afterwards teach his Roman or Turkish master: Saracen carries the knowledge from Persia and Byzantium to Spain: Spain or Byzantium pass it on to Italy: Hollander learns in Italy, and his posterity, exiled by civil strife, flee to Lambeth, and take the art with them to a hospitable home in the British Isles: whence in later times it speeds across the Atlantic to the newly found continent of America.

And, by the way, observant and inventive units add their own touch of genius; and the art gathers utility, variety, attractiveness; wins the favour of princes; becomes installed in palaces and temples; and, ebbing and flowing with the chameleon tides of national prosperity, advances as genius, enterprise, patronage and fashion supervene, or languishes by dearth of them.

Not only in the service of Art and Architecture, however, but also in the service of History, has Pottery attained an honoured place. Papyri, parchment and paper have been the custodians of records of many momentous events; implements of fractured flint, hieroglyphics carved in stone, bronzes and sculptures from the bottom of the sea, coins from buried caskets, jewellery and apparel from tombs, have each in turn preserved for ages a simple truthful record of facts, and at last delivered it safely into the hands of alert and sympathetic antiquarians: so also Pottery, yea even castaway potsherds—of which Dr. Petrie speaks as "the commonest relic in all countries" and as "the key to all historical excavation" (*Leisure Hour*, 1891)—share the honour.

The discovery and identification of NAUKRATIS is a brilliant example. Professor Petrie wrote of it thus:—"There I met a sight which I had never hoped for—almost too strange to believe. Before me lay a long low mound of town ruins . . . . wherever I walked I trod on pieces of archaic Greek pottery; soon I laded my pockets with scraps of vases and of statuettes, and at last tore myself away, longing to resolve the mystery of these Greeks in Egypt. . . . . The next season I returned to this curious site, determined to understand its history. The only place that I could find to live in about there was an

Memorial tablet of E-an-na-du, Governor of Shirpula (Lagash) about B.C. 4500. (B.M.)
(By permission of the Director of the British Museum.)

old country-house of a Pasha; and while looking at it I noticed two blocks of dark grey stone by the side of the entrance. Turning one of them over I there saw the glorious heading ΗΠΟΛΙΣ ΗΝΑΥΚΡΑΤΙ . . . . a decree of the city of Naukratis was before me, and the unknown town now had a name; and that a name which had been sought for, often and far from this place. . . . . All that day Naukratis rang in my mind, and I sprang over the mounds with that splendid exultation of a new discovery long wished for and well found." (*Ten Years' Digging in Egypt*, R.T.S.)

Another, and possibly an even more important example of the service of the potter's art to history, is found in the inscribed baked-clay tablets of Babylonia and Assyria. Scores of thousands of these terra-cotta documents, recording ordinary and extraordinary incidents of daily life 2500 to 5000 years ago, are included in the ceramic treasures of British and Foreign national museums,—one such tablet, indeed, an illustration of which we are permitted to reproduce by the Director of the British Museum, being assigned to a remote epoch—4500 B.C.—(Plate I.).

Until the discovery and deciphering of these inscribed tiles, which had "remained in darkness while the long roll of European history was enacted," no authentic record of the long-past history of these ancient kingdoms was available, and historians bewailed the fact that nothing was known of either, beyond what is mentioned in Scripture.

Painstaking transliteration and translation by learned palæographists—of whom the premier honours belong to Sir Henry C. Rawlinson and Dr. Hincks—revealed the far-reaching and momentous fact that these tablets were the imperishable archives of ancient civilizations, enabling us to peer down the long vista of time and read royal letters of Babylonian and Assyrian kings (Plate II.), court decrees, private deeds of land, histories, hymns, tables of arithmetic, business accounts, vocabularies, sign lists, even spelling-books, dating back 2300 years, and often very much more.

Of many of these, English translations are given in Smith's *Assyrian Discoveries*, and in works by Sir H. C. Rawlinson, and those who have made use of his system and followed up his labours.

What paper and parchment are to us, these baked-clay tiles seem to have been to them, for they too were a literary people (*Leisure Hour*, 1885, p. 359); for want of enduring records such as these, the ancient history of Persia is mostly lost; and if the doings of men have as much value for posterity as they certainly have interest, then it would follow that our own archives of to-day and those of other great nations would more prudently be entrusted to ceramics than to decayable, combustible animal and vegetable substances, so frequently employed.

Listen to Dr. Petrie's lamentation as he slowly, with infinite gentleness, unfolded the half-charred papyri at Tanis:—"A yet more heart-rending sight

was the pile of papyrus rolls, so rotted that they fell to pieces with a touch, showing here and there a letter of finest Greek writing." (*Ten Years' Digging in Egypt*, p. 33, R.T.S.) On the other hand, of clay-tablets he writes:—"During the age of the decline of Egyptian power in Syria, when the great conquests of Tahutmes I. were all gradually lost, a splendid store of information was laid by for us in the cuneiform correspondence at Tell el Amarna" (Plate II.). "The clay tablets, mostly from Syria, ... were deposited in 'the place of the records of the palace of the King,' as it is called upon the stamped bricks which I found still remaining there." (*Syria and Egypt*, p. 1, Methuen.)

Again—to quote Dr. S. Birch, F.S.A.—"While the paper and parchment learning of the Byzantine Alexandrian schools has almost disappeared after a few centuries, the granite pages of Egypt and the clay-leaves of Assyria have escaped." (*Hist. of Ancient Pottery*, p. 53.)

The chronological order adopted in this review is unavoidably open to adverse criticism, for with so much complex concurrent international activity, events occur in such manner as to prevent consecutive narration or tolerable sequence, and so opens the door to criticism.

Profound questions such as the precedence of Akkad or Egyptian must obviously be left to authorities, one of whom—Dr. E. A. Wallis Budge, Litt.D., etc.—mentions the existence of highly organised states or confederations of Babylonian cities at a period indicating that the beginning of Sumerian civilisation may date even from 8000 B.C. (*Guide to Babylonian and Assyrian Antiq. in Brit. Museum*, p. 3.)

In another place Dr. Budge writes:—"The importance of the Asiatic element in the historical Egyptian has been understated . . . . the newcomers appear to have taught the men they vanquished the arts and crafts of which up to that time they were ignorant." (*History of Egypt*, vol. i. pp. xiii and 38, Kegan Paul & Co.) And Professor A. H. Sayce has written:—"The dynastic Egyptian had come from Asia." (*Connoisseur*, Nov. 1902.)

Hence it would seem justifiable to give precedence to Babylonian phases of decorative ceramics, even though positive evidence of priority in the application of the art to the embellishment of buildings over that of Egypt may be slender, or possibly wanting; and the fine enamelled-brick reliefs of Babylon, probably made long after the decorative tilework of both Tell el Amarna and Tell el Yehûdîyèh.

Babylonian and Assyrian.—Babylonia is situated in the valley of the Euphrates, some 200 miles N.W. of the head of the Persian Gulf, in Asiatic Turkey. Approximately it extends from about the 30th to the 35th parallels of N. latitude, and the 42nd to the 48th degrees E. longitude.

It should be mentioned that there are ruin mounds of an ancient Roman stronghold, called "ruins of Babylon," close to Cairo; but this apparently is

Letter from Tushratta, King of Mitani, to Amenophis III., King of Egypt, about B.C. 1450. (British Museum.)

(By permission of the Director of the British Museum.)

merely an instance of the application of the name of a famous city to another place, just as European names are used in America and Australia.

The origin of Babylonian art is wrapt in profound mystery, and it is beyond the scope of this volume to attempt to penetrate or elucidate that mystery; evidence of the existence of the art and of its character only must suffice.

Anderson states that "the culture of the Akkads must have reached its complete form between 5000 and 6000 B.C." (*Story of Extinct Civilization*, p. 36, Newnes.)

Fortnum asserts that "There can be little doubt that at a remote period glass glazed wares were made throughout the Babylonian and Assyrian kingdoms as well as in Egypt, and that from one or the other of these great centres of early civilization the mode of fabrication spread to surrounding countries." (*Maiolica, Ashmolean Museum*, p. 9.)

Sir George Birdwood, K.C.I.E., M.D., has said, "Babylonia was architecturally and artistically . . . . entirely a creation of the potter." (*British Clayworker*, August 1899.)

Professor Herman v. Hilprecht has written, "We are faced with the strange but undeniable fact . . . . that Babylonian art 4000 B.C. shows a knowledge of human forms, an observation of the laws of art, and a neatness and fineness of execution far beyond the product of later times. The flower of Babylonian art indeed is found at the beginning of Babylonian history." (*Recent Research in Bible Lands*, p. 88, Wattles & Co., Philadelphia.)

Of excavations and discoveries in Babylonia: in the year 1854, at Birs Nimrûd, near Hillah, on the banks of the Euphrates, about 70 miles south of Bagdad, Sir Henry C. Rawlinson directed excavations on the traditional site of the Tower of Babel, and from inscriptions found it was proved that the building was the once famous tower of the seven planets, built upon an ancient site of a temple by Nebuchadnezzar II., king of Babylon, B.C. 604–562. Each story of the tower was constructed of bricks, glazed with the colour attributed to the particular planet to which it was dedicated. (See *Guide to Babylonian and Assyrian Antiquities in the British Museum.*)

Of this structure W. K. Loftus, F.G.S., writes, "There are few ruins in the world which have excited such general interest and speculation regarding their object and origin as the vitrified brick edifice which crowns the summit of Birs Nimrûd. . . . . Sir Henry Rawlinson ascertained that the structure consisted of six distinct platforms or terraces. Each terrace was about 20 feet in height and 42 feet less horizontally than the one below it. The whole were so arranged as to constitute an oblique pyramid. . . . . Upon the sixth story stands the vitrified mass concerning which such discussion has arisen and which it is now suggested was the sanctum of the temple. Built into the corners of the stories were cylinders of Nebuchadnezzar, designating the

whole structure "the stages of the seven spheres of Borsippa"; each story was dedicated to a planet, and stained with the colour peculiarly attributed to it in the works of the Sabean astrologers, and traditionally handed down to us from the Chaldeans. The lowest stage was coloured black in honour of Saturn; the second, orange, for Jupiter; the third, red, for Mars; the fourth, yellow, for the Sun; the fifth, green, for Venus; the sixth, blue, for Mercury: and the temple was probably white, for the Moon." (*Chaldæa and Susiana*, p. 28, Nisbet.)

Mr. Loftus also gives Sir Henry C. Rawlinson's translation of the cuneiform record, which states that Nabu-Kuduri-uzur's restoration took place 504 years after the original foundation by Tiglath-Pileser I., who dates as far back as 1100 B.C. The existing edifice is regarded as a *facsimile* of the one destroyed, which Nebuchadnezzar even in his day found in a decayed and ruined state.

In A.D. 1888 an American expedition was equipped and sent out by the University of Pennsylvania, and directed its efforts chiefly to vast ruin mounds at Niffer, Nuffar, or Nipper, in the northern plains of Babylonia.

Like most expeditions of a similar nature, the members experienced unforeseen perils and privations, including the wrecking of some of the party off the island of Samos, as they were being conveyed in a French steamer from Smyrna to Alexandretta.

Yet, notwithstanding the immense difficulties of access to, and the weird silence and desolation of the locality, together with inter-tribal strife, treachery, torrid heat and pestilence, the expedition made and recorded remarkable discoveries. Herman v. Hilprecht, Ph.D., D.D., the Assyriologist of the expedition, writes: "The terraces of the temple of Ekur . . . . rose even more distinctly out of the rubbish mass which had grown above it through millenniums. . . . . The platform of the first king of Ur, who built here about 2800 B.C., was soon reached, but deeper still sank the shafts of the Americans . . . . numerous bricks bearing the name of the great Sargon, who, 3800 B.C. had extended his powerful empire to the shores of the Mediterranean, came forth to the light of day under pickaxe and shovel. By this the expedition supplied irrefutable proof of the historical character of this primitive Semitic kingdom. . . . . But although the excavations have gone already (March 1896) 35 feet below the platform of King Ur-gur of Ur (about 2800 B.C.), not yet have they reached the deepest foundations of this venerable sanctuary, whose influence for over 4000 years had been felt by all classes of the Babylonian people. . . . . In the presence of this fact we begin to have some notion why Nippur is spoken of as the oldest city of the earth in the old Sumerian legends of the creation. . . . . My own investigations . . . . have shown that about 1000 years before the so-called first dynasty of Ur, there was a still earlier powerful dynasty of Babylonian kings." Dr. Hilprecht then makes the

remarkable statement which we repeated on a previous page, to the effect that Babylonian art was at its zenith 4000 B.C. (*Recent Research in Bible Lands*, pp. 57, 88, Wattles, Philadelphia.) In another publication, Dr. Hilprecht records the results of the memorable *Fourth Expedition*, 1898–1900, when hundreds of important antiquities were discovered, and the library and Priests' school at Nippur located and partially excavated. (See *Exploration in Bible Lands during the 19th Century*.)

More recently Assyriologists sent out by the German Oriental Society, excavating on a portion of the site of ancient Babylon, cleared away the rubbish from one of the great city gates and revealed a remarkable series of enamelled-brick reliefs, some of the drawings of which we are permitted to illustrate (Plate III.).

In a lecture about these excavations by Dr. Friedrich Delitzsch, delivered in Berlin on 12th January 1903, in the presence of His Majesty the German Emperor, the learned Professor said (translated), — "King Nebuchadnezzar relates that he adorned the city-gate of Babylon, which was dedicated to the goddess Ishtar, with bricks on which rêmu and immense serpents, standing erect, were depicted: and the recovery of the Ishtar gate, together with the work of laying it bare to a depth of 14 metres, where the water-level begins, constitutes one of the most important achievements of recent years in our excavations on the site of Babylon. . . . How the pulses quicken when, after long weary weeks of work with pick and spade, under the scorching rays of an Eastern sun, the long-sought building is disclosed—when, inscribed on an immense slab of stone, the name 'Ishtar-gate' is read, and piece by piece the great double gate of Babylon, flanked northward by three mighty towers, emerges from the bowels of the earth in splendid preservation. Whichever way we look on the wall-surfaces of the towers as well as of the gateway passages, every part swarms with reliefs, rêmu coloured on their surface, with enamels standing out against the background of deep blue.

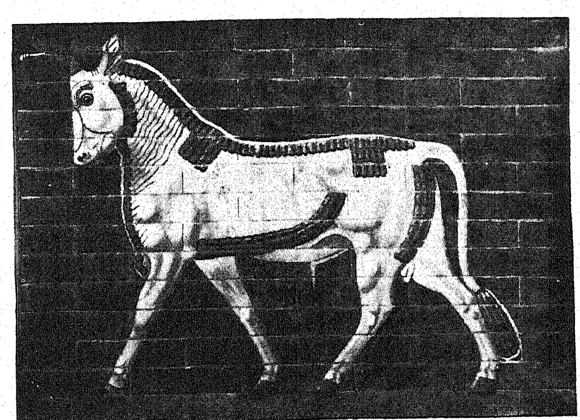


FIG. 5.—Enamelled-brick reliefs from Babylon. (*By permission of Williams & Norgate, London.*)

Mightily the wild ox strides with long step, and neck proudly raised, with horns bent threateningly forward, ears turned back, nostrils dilated, the muscles tense and swollen, the tail lifted and falling away in a vigorous curve

—all as nature dictates, yet enhanced by an air of nobility. If the smooth skin is white, the horns and hoofs are of a brilliant golden hue; if the skin is yellow, then both are of malachite green, while the mane in each case is painted a deep blue. Of truly noble appearance, however, is a white bull in relief, of which not merely the horns and hoofs but the mane as well are painted sap-green.

Such is the rè ēm of the gate of Ishtar, through which the Procession street of Marduk led, a worthy companion to the well-known "Lion of Babylon," which adorned that famous street. And besides this the German Oriental Society has also presented Biblical science with another animal of the rarest kind, with a fabulous beast which our religious training has made us well acquainted with, and which must make a fascinating impression on all who approach the palace of Nebuchadnezzar through the Ishtar gate—I mean the Dragon of Babel (Plate III.), "with neck extended far forward and poison-threatening glance, the monster strides along"—it is a serpent, as the long double-tongued head, the long scaly body, and the serpentine tail clearly show; but it also at the same time possesses the fore legs of the panther, while its hind legs are armed with immense talons: and in addition it carries long straight horns on the head, and a scorpion sting at the end of the tail." (*Babel and Bible*, p. 166, Williams & Norgate.)

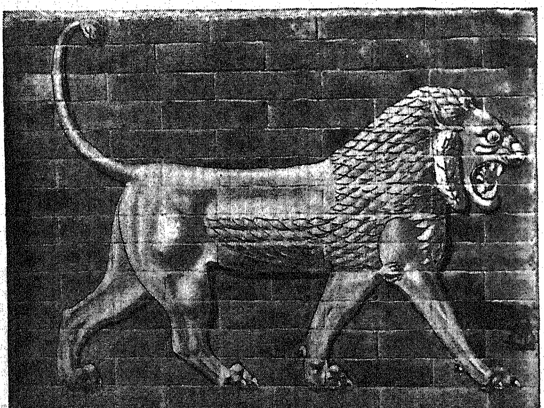
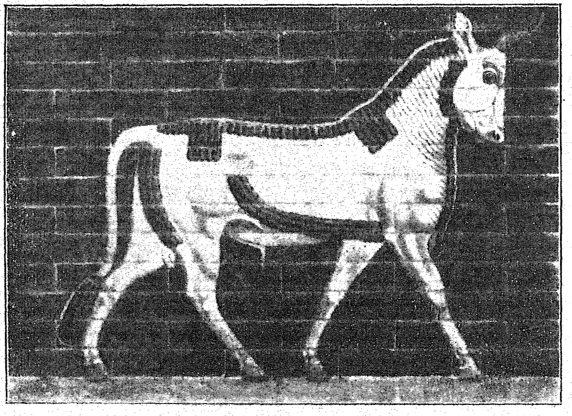


FIG. 6.—Enamelled-brick reliefs from Babylon. (*By permission of Williams & Norgate, London.*)

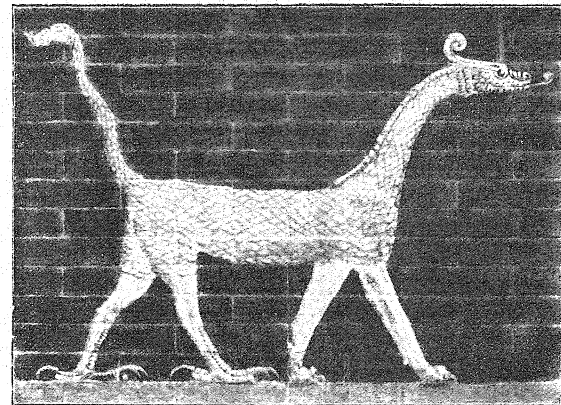
The words cited in the above passages, Dr. Delitzsch explains subsequently, are from an essay by Walter Andrae, in which he describes in detail the painted representations in relief on brick of the wild ox as well as of the dragon. (*Ibid.*, p. 221.)

Dr. Bruno Güterbock, Secretary of the German Oriental Society, very courteously informs the writer that the enamelled-brick reliefs have partly been left *in situ* at Babylon, but 400 chests of bricks and pieces of bricks have by permission of the Turkish Government been removed to Berlin. The clearing and recomposing of these is an operation that will take a very long time, and years may elapse before these reliefs can be restored to their former glory. Then they will probably be exhibited for a time in Berlin, and partly perhaps sent back to Constantinople.

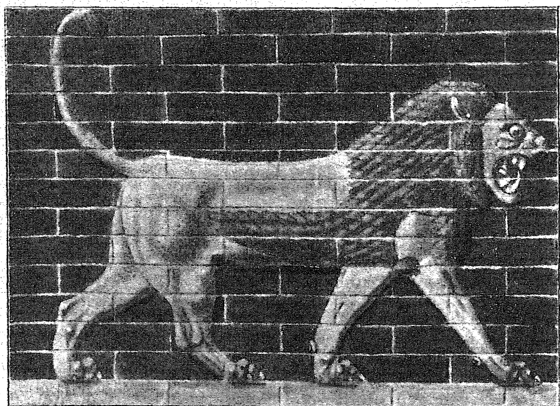
ENAMELLED-BRICK RELIEFS FROM BABYLON



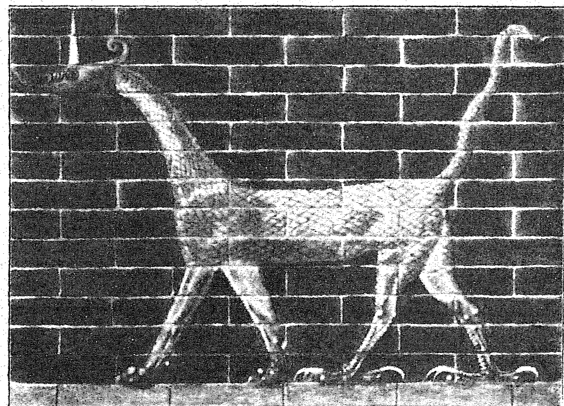
The Wild-Ox, in white and green



The Dragon of Babel, in white and yellow



The Lion of Babylon, in yellow and green



The Dragon of Babel, in yellow and green

From "BABEL UND BIBEL" by DR. FRIEDRICH DELITZSCH, Professor of Assyriology in the University, Berlin

By permission of WILLIAMS & NORGATE, Publishers, LONDON

The representations of animals, however, only form part of these treasures; evidence of beautiful geometrical and conventional designs worked out in enamelled brickwork in several colours, chiefly dark blue, turquoise, yellow and white, has been gained.

Brongniart mentions enamelled bricks found in the ruins of Babylon, and remarks that they cannot well be of more recent date than the time of the destruction of Babylon by Darius, 522 B.C., and were probably much older. He refers also to the travels of Mr. J. C. Rich around Babylon, and of his finding a great quantity of glazed tiles of which the colour and brilliance are astonishing. Brongniart further explains that small scales or chippings of the glazes or enamels of specimens of these ancient enamelled bricks were examined in the laboratory at Sèvres by M. Salvetat and M. Lenormant, and they reported that the glaze did not contain either lead or tin, and could not therefore be considered like faïence enamel, but were more like a vitreous coating or glaze composed of "*silicate-alcalin d'alumine*," coloured by metallic oxides, analogous to the glazes of the Egyptians. (*Traité des Arts Céramiques*, vol. ii. p. 89.)

The comparative durability of Babylonian ceramics when compared with stone may be inferred from a remark by a traveller who recorded his impressions in *Blackwood's Magazine*, June 1863. Referring to some ruins between Mohawell and Hillah, he wrote: "The bricks were square, of large size and beautiful make: the angles of some clear and sharp, as if the brick had but left the kiln yesterday, instead of nearly twice two thousand years ago. Turning into a little hollow way between the mounds, we came suddenly upon the colossal stone lion. Time, with his leaden hand, had knocked away at all the sharp angles of the statue. The features of the lion are completely obliterated, as are also those of the prostrate form that lies so helpless, so utterly and wholly human, beneath the upraised paw of the king of beasts."

Respecting Assyria: Nineveh, the ancient capital of Assyria, was, according to Scripture, "*an exceeding great city*" (Jonah iii. 3); it is said to have had walls 100 feet high, broad enough on the top for three chariots to run abreast: 1500 towers are said to have studded these immense walls, and accommodated the guard. This city "stood from obscure antiquity . . . . till it was destroyed by the Medes and Babylonians, 607 B.C." (Bagster's *Teachers' Bible*.) In 1820 Mr. J. Rich examined some mounds at Kuyunjik—the Turkish name given to a group of mounds situated on the east bank of the river Tigris, opposite to the town of Môsul—and after careful examination formed the opinion that Kuyunjik was part of the site of the ancient city Nineveh. (*Guide to the Babylonian and Assyrian Antiq. in British Museum.*)

In 1842 M. Botta, French consul at Môsul, conducted excavations both at Kuyunjik and at Khorsabad, most of his valuable findings going to Paris. In 1846 Sir A. H. Layard carried out further excavations in the mounds of

Kunyunjik and Nimrûd, and succeeded in locating the site of the great palace of Senacherib at Nineveh; making careful sketches on the spot, and sending most of the archæological treasures he unearthed to the British Museum. But many of the antiquities he saw were in such an advanced stage of decay that they could not be removed.

In his *Monuments of Nineveh* Sir A. H. Layard tells us that the sculptures and bas-reliefs stood in the walls of palaces and temples which had been buried for nearly twenty-five centuries beneath a vast accumulation of earth and rubbish. Some of these works of art he attributes to the remotest antiquity, others to the later dynasty which ruled over Assyria at the time of the fall of the empire about 600 B.C. The north-west palace is believed to be a most ancient Assyrian edifice, and the south-west one the more recent; and it seems to have been from the former that Layard obtained the painted bricks.

By the kind permission of Mr. John Murray, of Albemarle Street, London, we are able to reproduce several coloured drawings from Sir A. H. Layard's great work, *Monuments of Nineveh* (Plate IV.). These substantiate the assertion that, notwithstanding the lapse of twenty-five centuries, their ornamental designs are still capable of yielding highly decorative effects, acceptable to the most cultivated minds in our own day.

Professor Sayce has explained that the Assyrians had originally migrated from Babylonia, and that they had carried with them the traditions of the art and architecture of their mother country. Consequently although in Assyria clay was comparatively scarce and stone plentiful, the Assyrians nevertheless did not forego the use of brick. The walls of Nineveh, in spite of their height, were constructed of brick, and it was only the basement of the palaces which was of stone. Hence we need not be surprised to find a slavish imitation of the style of architecture, rather out of place in the country to which it had been transferred. Vast platforms of bricks were used upon which the temples and palaces were built. In Babylonia these were necessary in order to secure the erections from destruction by floods in a marshy country, but in Assyria these precautions were unnecessary.

Mr Joseph Mayer, F.S.A., of Liverpool, states that—"The Assyrians used terra-cotta largely in the ornamentation of their houses . . . . a line of granite slabs sculptured with the great doings of their monarchs formed a lofty wainscot to their halls, whilst the short corridors leading from one to the other were decorated with colossal bulls, etc. Above these slabs ran a line of tilework of very graceful and ingenious device, but subdued in tone. Pale blue, olive green, and dull yellow predominated, with white and black and brown occasionally introduced; red was rare." (*History of the Art of Pottery*, p. 11.)

Dr. Samuel Birch, LL.D., F.S.A., *P*.S.B.A., wrote as follows:—"The

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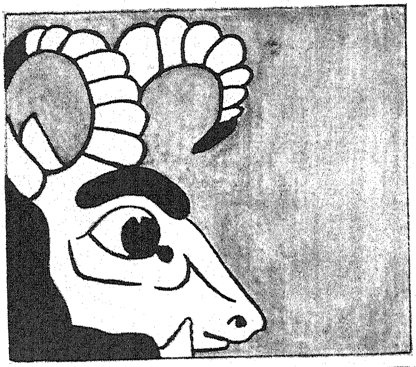

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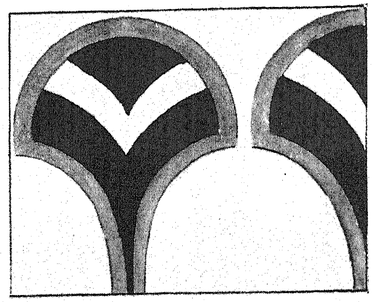

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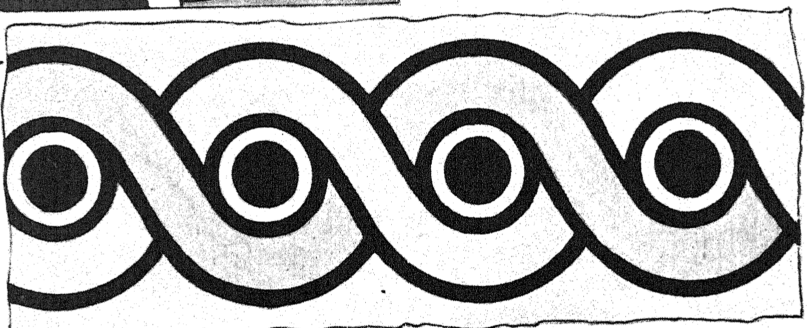

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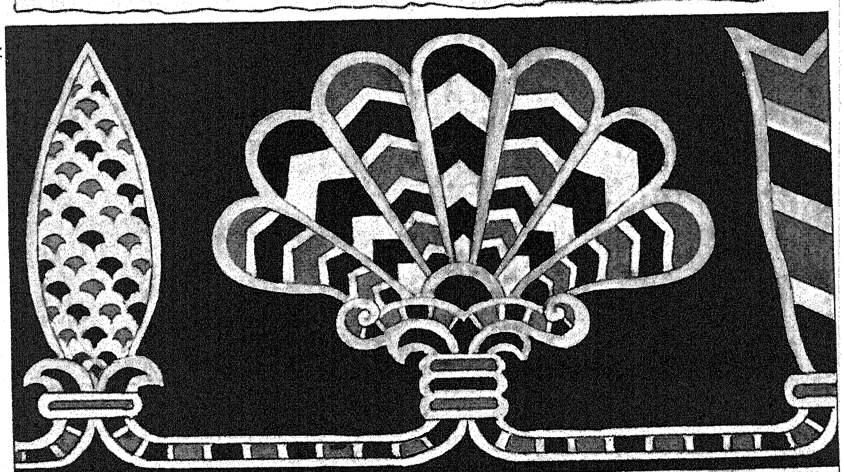


From Sir A. H. Layard's "*Monuments of Nineveh,*" Pl. LXXXIV., LXXXVI., LXX

(By Permission of Mr. John Murray, Albemarle Street, London)

application of a glaze to bricks in order by this means to give the appearance of fayence to the sides of the rooms . . . . was probably derived by the Assyrians from the Egyptians, who at a very early period had inlaid in this manner the chambers of the pyramid at Saqqara, and later the temple of Rameses III. at Tel el Yahoudeh. . . . . The glazed or enamelled bricks from Nimrûd are of the usual kiln-dried kind, measuring $13\frac{1}{2}$ inches square and about $4\frac{1}{2}$ inches thick. They were laid in rows horizontally above the slabs of sculpture of the Mosul marble, and seem to have been employed in the construction of cornices. They are glazed on one of the narrow sides or edges only having on this edge various patterns, chiefly of an architectural nature, such as guilloche or chain ornaments, bands of palmettes . . . . and fleurettes or flowers of many petals. The colours employed were blue, black, yellow red, and white. The glaze, which is much decomposed, easily exfoliates and the colours have lost much of their freshness. It would appear that patterns of tolerably large size were executed in this manner, each brick having its appropriate portion enamelled upon it. . . . . The analysis made in the Museum of Practical Geology of the colours of the enamel . . . . shows that the opaque white was produced with tin, the yellow with antimoniate of lead or Naples yellow, the brown with iron, the blue and green with copper. The flux and glazes consisted of silicate of soda aided by lead. The body or paste of the brick is of a very calcareous quality." (*History of Ancient Pottery*, pp. 89–90, Murray.)

About 1850 Mr. Loftus visited some extensive mounds at Warka, in Chaldæa, where both early cuneiform inscriptions as well as Greek records had been discovered. The immensity of the ruins and the sacred character attached to them indicated that this site was that of Erech (Gen. x. 10), or the Orchoë of the Greeks, where, he says, a university existed in the time of Alexander the Great. (*Chaldæa and Susiana*, p. 161.) He refers to finding several fragments of coloured enamelled bricks similar to those found on the ruins of the Kasr at Babylon ; and gives some very instructive and interesting sketches of a mode of ornamenting walls at Warka by means of small yellow terra-cotta cones $3\frac{1}{2}$ inches long. These, he remarks, "were undoubtedly much used as an architectural decoration in Lower Chaldæa, and always in connection with sepulchral remains." (*Chaldæa and Susiana*, pp. 187–189, Nesbit.) Judging by Mr. Loftus's drawings, the effect is rather like mosaic, and this Chaldæan example indicates the great antiquity of such styles of mural embellishment.

Ancient Egyptian.—"When Abraham visited Egypt the three pyramids of Gizeh had been already built, and the land had witnessed the rise and fall of two empires." (Bagster's *Teachers' Bible.*)

In his interesting book, *Ten Years' Digging in Egypt*, Professor Flinders Petrie, referring to the evidence that the cliffs all along the Nile are worn by water running at a great height, remarks that even then "man was there

. . . . as his rude flint implements, river worn and rolled, high upon the hills, now show us." Coming to a later age, when the Nile had fallen to its present level, he continues, "The civilization that we find in the earliest known history appears elaborate and perfect" . . . . "completely master of the arts of combined labour, of masonry, of sculpture, of metal-working, of turning, of carpentry, of pottery, of weaving, of dyeing, and other elements of a highly organized social life; and in some respects their work is quite the equal of any that has been done by mankind in later ages." (*Ten Years' Digging in Egypt*, pp. 149, 151, R.T.S.)

For the sake of perspicuity, one eminent writer classifies Egyptian periods into three divisions, viz.—PREDYNASTIC, all that occurred before B.C. 4777. PRIMITIVE, the first three recognised dynasties, B.C. 4777 to B.C. 3998. HISTORIC, from B.C. 3998 to the time of the Romans.

"In respect of the predynastic antiquities of Egypt," writes Dr. Budge, "almost the latest possible date that can be assigned to them is B.C. 5000." (*History of Egypt*, vol. i. p. 33, Kegan Paul, Trench & Co.) Yet even of this remote age there have been found indications of glazed tilework. During the winter of 1894–1895 Dr. Petrie conducted excavations on a site bordering on the desert between Ballas and Naqada, some thirty miles north of Thebes, where, amongst other things, he found pottery and blue-glazed quartz, and he concluded that "the art of glazing was well known." (*History of Egypt*, vol. i. p. 9, Methuen.) Many of the antiquities of Naqada have since then been independently assigned to predynastic times. (See Dr. Budge's *History of Egypt*, vol. i. p. 12, Kegan.) Again, at Hierakonpolis, excavations were made in 1898, under the direction of Mr. Quibell, and amongst the antiquities discovered was a small glazed plaque, with a perforated tenon at the back to enable it to be attached to a wall. This is assigned to a predynastic age, about 4800 B.C. (*Hierakonpolis*, pl. xviii. fig. 2, E.R.A.)

These are very meagre indications of the early practice of decorative ceramic art in Egypt, but meagre though they are, their significance is undeniable. Had the Abu Roash pyramids remained, something might have been learned from them, but the hand of the despoiler and the utilitarian has obliterated these memorials for ever. Mr. John Ward, F.S.A., tells us that they have nearly all been quarried away, and "nothing but their sites remain, marked by heaps of broken stones and granite." (*Windsor Mag.*, Jan. 1902.)

With regard to the Primitive period—B.C. 4777 to B.C. 3998—by the courtesy of Dr. Petrie we are able to illustrate an example of glazed tile of this period; namely, a small tenoned tile from Naqada, of 1st dynasty, B.C. 4700, completely covered with fine turquoise-blue glaze of a very lively tint, the body consisting of white vesicular granular substance, slightly friable, and probably highly siliceous (fig. 7).

Another example of 1st dynasty glazed tile in Dr. Petrie's collection is a

ribbed-faced tenoned tile about $5\frac{3}{4}$ inches long and a similar width, probably, when whole. It is glazed all over with turquoise glaze of pale greenish tone; the tenon is dovetailed, and there is a hole perforated in the back of the tile, which would render it suitable for attachment to a wall, to represent papyrus stems in an architectural or decorative scheme. The body of this tile is also white, granular, semi-vitrescent, like petrified snow.

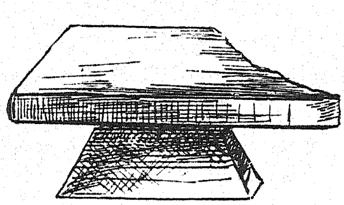


FIG. 7.—Blue-glazed tile from Naqada, B.C. 4700. (W.M.F.P. Coll.)

Abydos, another site where vast remains of early dynasties have been found, had apparently yielded no fragments of glazed tiles or decorative faience until the season before last, when Dr. Petrie discovered some wall tiles in the great brick-built mounds there.

In a letter to the *Times* of 29th June 1903 the learned Professor explains that the clearance of the old temple site over several acres brought to light no less than ten successive temples, ranging in age from 5000 to 500 B.C., the most striking change appearing about the period of the 4th dynasty, when the temple was abolished, and only a great hearth of burnt-offering is found, full of votive clay substitutes for sacrifices. This, Dr. Petrie tells us, exactly agrees with the account of Herodotus, that Cheops had closed the temples and forbidden sacrifices.

FIG. 8.—Green-glazed relief tile from Abydos Temple, 1st dynasty, 5 ins. × $3\frac{3}{4}$ ins. × $\frac{3}{4}$ in. (W.M.F.P. Coll.) (See *Abydos*, ii. pl. i.)

In the way of pottery, the explorers, including Dr. Grenfell and Dr. Hunt, found among other things part of a large green-glazed vase, with King Menes' name inlaid in purple; thus giving evidence of polychrome glazing thousands of years before it was previously known of; and he adds, "The free use of great tiles of glaze for wall coverings shows how usual the art was then."

By the kindness of Dr. Petrie, we are able to illustrate several remarkable tiles of green-glazed pottery from Abydos.

Fig. 8 represents a high-relief tile, formed from the flat by cutting out the relief by hand while the clay tile was in a sun-hardened condition, and after-

wards glazing and burning. It has no dovetailed tenon or groove at the back, and was probably a votive offering rather than a wall tile. The figure is of negroid type of a prehistoric people; the hieroglyphic inscription being translated by Dr. Petrie as the name of a chief, "TERA-NETER" = devoted to God; of the fortress of the ANU, in the town of Hemen. This and another tile found at Abydos introduce a style of relief work on glazed tiles not hitherto found of such an early period. (See *Abydos*, ii. p. 25, E.E. Fund.)

Fig. 9 illustrates a large green-glazed wall tile from Abydos, in which the surface is formed to represent papyrus stalks in low relief. This tile measures $11\frac{1}{2}$ inches by $6\frac{2}{5}$ inches, and is $\frac{3}{4}$ inch thick. It has a dovetailed tenon at the back, through which holes have been drilled or made to enable a copper wire to be passed through the tenon, and so assist in securing the tile to the building without disfiguring the tile face. Many smaller turquoise- or green-glazed wall tiles were also found, having plain convex faces, and at the back dovetailed tenons. These are similar to those found at Sakkarah; they measure about $2\frac{7}{8}$ inches × $1\frac{3}{4}$ inch.

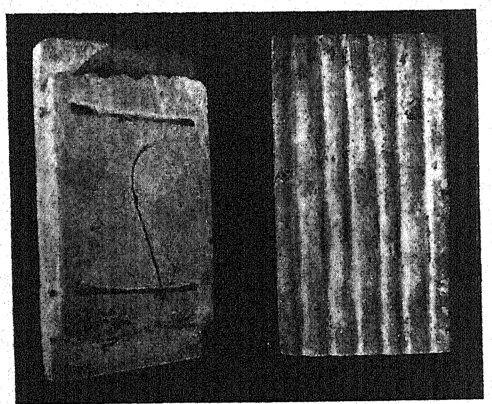


FIG. 9.—Tenoned ribbed-faced glazed tile from Abydos Temple. (W.M.F.P. Coll.)

The effect produced upon a wall when large numbers of these small convex-faced glazed tiles are placed upon it must have been peculiar, and certainly is suggestive. Such a surface would at least not be open to the criticism sometimes flung at modern tilework of being a dead, flat, uninteresting one.

Very pretty green-glazed pottery capitals of small decorative columns were also found, and are illustrated in Dr. Petrie's *Abydos*, ii., E.E. Fund. These pottery-ware and tiles, together with finely wrought ivory carvings, and carvings of limestone, slate, and alabaster, have drawn from Dr. Petrie the statement, "We must now reckon the earliest monarchy as the equal of any later age in such technical and fine art." (*Times*, 29th June 1903.)

Of decorative ceramic antiquities of the Primitive period, those of Sakkarah appear equally important. This district is an extensive ancient cemetery, pitted all over with tombs, situated about 12 miles south of Cairo, and believed to be the burial-place for Memphis. There are eleven pyramids at Saqqara, one of which is built in the form of steps and known as the Step pyramid. This is supposed to be the most ancient of them all, and is ascribed by Dr. Budge to King Tcheser of the 3rd dynasty, B.C. 4155 *circ.*

Fifty years or so ago, Dr. Samuel Birch, when referring to ancient

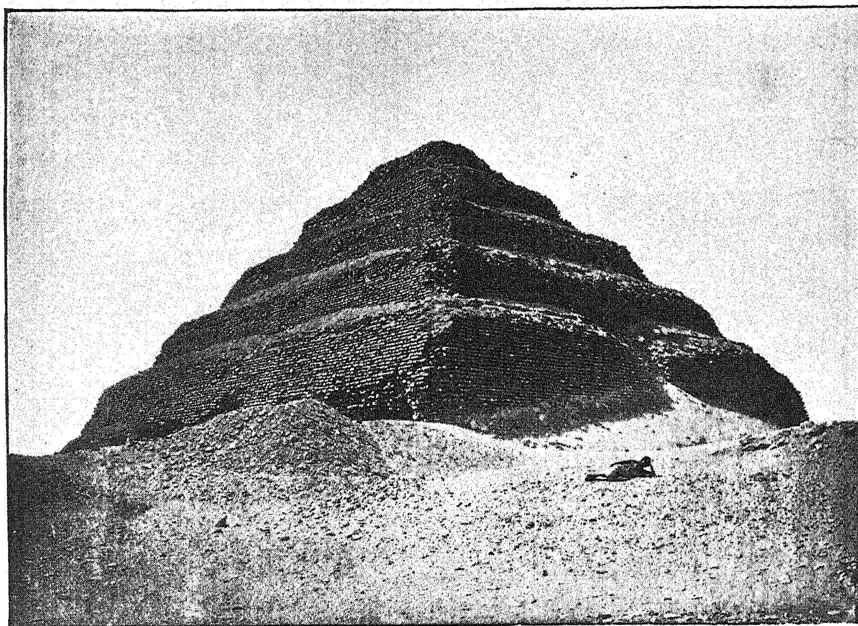


Fig. 10.—Step Pyramid of Sakkarah. (Dr. Petrie's *History of Egypt*, vol. i. p. 22, fig. 17. *By permission of Methuen & Co.*)

Egyptian blue porcelain wrote:—"One of the earliest instances of its application is to decorate the jambs of an inner door of the pyramid at Saqqara, in the style of the chimney-pieces plated with Dutch tiles which were in fashion about half a century ago. The tiles are 2 inches long by 1 broad, and almost an eighth of an inch thick. Some are of a bright blue colour, slightly convex on the exterior, having a plate behind, which was perforated horizontally, and was let into a layer of plaster—a wire having

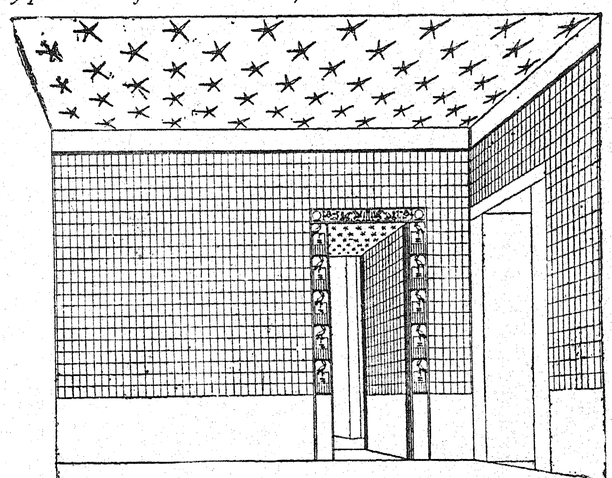


Fig. 11.—Interior of Step Pyramid. (See *Egypt. Archæology*, p. 267. *By permission of Grevel & Co.*)

been probably run through the tiles to secure them to the jamb." (*History of Ancient Pottery*, p. 49, Murray.)

Professor Maspero, in his *Egyptian Archæology*, gives a restored representation of the use of tiles in this instance, which, by consent of Messrs. H. Grevel & Co., of London, we are able to reproduce. The learned Professor remarks that up to the beginning of the 19th century "one of the chambers in the Step pyramid at Sakkarah yet retained its mural decoration of glazed ware. For three-fourths of the wall surface it was covered with green tiles, oblong in shape, flat at the back, and slightly convex on the face. A square tenon, pierced through with a hole large enough to receive a wooden rod, served to fix them together in horizontal rows. The three rows which frame in the doorway are inscribed with the titles of Zeser, a Pharaoh who belonged to the third Memphite dynasty." (*Egyptian Archæology*, p. 268, Grevel.)

FIG. 12. — Convex-faced tile from Sakkarah. (*By permission of Grevel & Co.*)

There are several specimens of these tiles in the British Museum, which Dr. Budge speaks of as "beautiful blue-glazed faïence tiles." (*Hist. Egypt*, vol. ii. pp. 8–9, Kegan.)

Respecting these antiquities, a very interesting translation from *Comptes Rendus* appeared in *The Pottery Gazette* of August 1900, p. 923. It reads thus:—"The question whether or no the ancient Egyptians really ever produced true porcelain . . . . has often been discussed. Brongniart, in his classic treatise on Ceramics, decided in the negative, and that all the specimens of porcelain found in Egypt were of Chinese manufacture. Le Chatelier, however, found, among a number of specimens submitted to him by Dr. Morgan, a fragment from a funeral statuette discovered at Saggarah (Memphis), which he regards as undoubtedly of porcelain, and the hieroglyphics inscribed on its surface leave no doubt as to its Egyptian origin. The body, which is hard and translucent, is of a pale blue colour, and exhibits the following composition, differing absolutely from that of Chinese porcelain:—Soda, 5·8 per cent.; cupric oxide, 1·7 per cent.; lime 2·1 per cent.; alumina, 1·4 per cent.; ferric oxide, 0·4 per cent.; silica, 88·6 per cent.

"It is thus a true soft porcelain, coloured blue by a little copper, and may be imitated by compounding a body from blue glass 40 per cent., ground sand 55 per cent., and white clay 5 per cent., the blue glass being prepared of such ingredients as to correspond to the formula 3·3 SiO_2, 0·23 CaO, 0·13 CuO, 0·64 Na_2O. Firing at 1050° C. gives a pale blue mass, which turns green if the kiln temperature be raised to about 1200° C. By reason of the low proportion of clay, the body when damp is of low plasticity, and is only suitable for moulding into solid shapes like the Egyptian statuette in question." (*Pottery Gazette*, August 1900, p. 923.)

Coming now to the Historic period, *i.e.* subsequent to B.C. 3998. The first

2400 years of this epoch appear to yield but little tangible evidence of the use of glazed tiles in building construction. Discoveries that would throw light upon this period may have escaped the writer's path of inquiry, or, on the other hand, the very monuments that could have enlightened us may have been destroyed, for Egypt has witnessed many despoilers, both native and foreign.

When referring to a visit to Beni Hasan, Mr. John Ward, F.S.A. (in *Pyramids and Progress*), remarks upon the beautiful paintings in the interiors of the rock-cut tombs of the great 12th dynasty (about 2600 B.C.), and of similar internal embellishment of Egyptian temples, near the site of Antinoë, but makes no mention of decorative ceramic products.

And in references to the exhibits of results of the 1902–3 season's excavations at Beni-Hasan by Mr. J. Garstang—shown in the rooms of the Society of Antiquaries, Burlington House, July 1903—there appears to be no mention of tiles.

From about B.C. 1550 to B.C. 1400 the Egyptian empire became powerful and extensive, Nubia, on one side, and Syria, on the other, owning her supremacy; it is in the latter part of this period we find a startling and most brilliant example of decorative ceramic art.

Professor Maspero writes,—"The fabrication of many-coloured enamels seems to have attained its greatest development under Khûenaten; at all events, it was at Tell el Amarna that I found the brightest and most delicately fashioned specimens, such as yellow, green, and violet rings, blue and white fleurettes, fish, lutes, figs, and bunches of grapes. . . . . However restricted the space, the various colours are laid in with so sure a hand that they never run one into the other, but stand out separately and vividly." (*Manual of Eg. Archæology*, p. 265, Grevel.)

Of this period Dr. Budge writes,—"The kings of the 18th dynasty were undoubtedly the greatest who ever occupied the throne of Egypt." . . . . "Hand in hand with the growth of power went increase in the wealth of Egypt, and the buildings which the greatest kings . . . . set up in their capital, Thebes, testify to the lavishness with which they spent." . . . . "The most interesting though certainly not the most important of the kings of the 18th dynasty was Amenhotep IV." During his reign painters, sculptors, and handicraftsmen of every kind developed a new style of Egyptian art, "characterised by great realism and freedom from conventionality." (*History of Egypt*, vol. iv., preface, and p. 161, Kegan.)

From Professor W. M. Flinders Petrie's account, it seems that early in the lifetime of Akhenaten (Amenhotep IV.) a great reformation in religion, ethics, and art was attempted, and with the object of shaking off the thraldom of the priests, the Egyptain court was removed from Thebes to a new city erected on an excellent site 200 miles or so further north, on the east bank of the Nile, which is now known to Europeans as Tell el Amarna.

The effect of this reformation on art, says Dr. Petrie, was "the direct study of nature, with as little influence as possible from convention; animals in rapid motion and natural grouping of plants were specially studied, and treated in a manner more natural than in any other oriental art." (*History of Egypt*, vol. ii. p. 219, Methuen.)

It was in 1891 that Dr. Petrie obtained permission to excavate at Tell el Amarna, and although debarred from examining the tombs, his "eagle eye" enabled him to fix upon a favourable spot for operations, and within three days of actually commencing work, he tells us, he found the painted stucco pavement of the palace, and within a fortnight the government were building a house to protect it; yet the site, which was originally discovered by Lepsius about fifty years earlier, had often been plundered and everything visible and portable removed.

"These painted pavements," writes Dr. Petrie, "were formed by laying a floor of mud bricks on the soil, covering them with a coat of mortar or fine concrete, about half an inch or an inch thick, so as to produce a level surface; and then facing that with fine plaster mixed with hair about one-eighth of an inch thick, on which the painting was executed. The colours were laid on while the plaster was wet . . . . after painting, the whole surface was polished and waterproofed." (*Tell el Amarna*, p. 12.)

From this pavement rose columns to support the roof, some of which Dr. Petrie describes as having moulded and glazed representations of creeping plants upon them, and capitals wonderfully inlaid with glazes. "On the walls," he writes, "glazed tiles were much used: all along the west side of the great hall of columns, fragments of green tiles with daisies and thistles were found scattered. Probably, therefore, there were more than 200 feet of this tile dado, with inlaid white daisies and violet thistles. From the number of pieces of tile with water pattern, lotus, fishes and birds, it seems that tiled floors also existed in the palace. The stone walls were inlaid with glazed figures of birds and glazed hieroglyphs." (*Tell el Amarna*, p. 28.)

"Here the jeweller's design was boldly carried in architecture on the largest scale, and high capitals gleamed with gold and gem-like glazes." . . . . "Large green reed signs and others all show that great inscriptions, intended to be seen from a distance, on the palace walls, were blazoned out in gorgeous coloured glazes, set in the white limestone." . . . . "In the same region were the pieces of glazed table dishes, imitating half gourds, half-fishes, etc., which show that the royal table service was an anticipation of modern taste." (*Tell el Amarna*, pp. 10–12.)

The technically interesting part of Dr. Petrie's discoveries, however, remain to be told; for he found the sites of three or four glass-works and two large glazing-works, wherein the "waste" heaps were full of fragments showing the methods employed. "We can therefore now trace," writes Dr. Petrie, "almost

every stage and detail of the mode of manufacture . . . . we are already familiar with the frits made by the Egyptians from the 12th dynasty onward for colouring purposes. These have been carefully analysed and remade by Dr. Russell; and we know that the components were silica, lime, alkaline carbonate, and copper carbonate, varying from 3 per cent. in delicate greenish blue up to 20 per cent. in rich purple blue. The green tints are always produced if iron be present; and it is difficult, if not impossible, to obtain silica from sand without the iron in it preventing the blues being produced. One of the first requisites, therefore, is to obtain the elements of the mixture free from iron. How this could be done was quite unknown until I picked up a piece of a pan of frit, which had been broken in the furnace and rejected before it was combined. This showed clearly through the mass the chips of white silica; and from their form they were clearly the result of crushing the quartz pebbles which are to be found on the surface of the desert, having been rolled down by the Nile from the disintegration of primitive rocks further south." . . . . "The lime, alkali, and copper had combined already, and the silica was in course of solution and combination with the alkali and lime." . . . . "The carbonic acid in the lime and alkali had been partly liberated by the dissolved silica, and had raised the mass into a spongy paste. With longer continued heating, the silica in ordinary samples has entirely disappeared, and formed a mixture of more or less fusible silicates. These made a pasty mass when kept at the temperature required to produce the fine colours; and this mass was then moulded into pats, and toasted in the furnace until the desired tint was reached by the requisite time and heat, and a soft crystalline porous friable cake of colour was produced." (*Tell el Amarna*, p. 25.)

"Among the furnace-waste," continues Dr. Petrie, "were many pebbles of white quartz. These had been laid as a cobble floor in the furnace and served as a clean space on which to toast the pats of colour, for scraps of the paste of frit were found sticking to one side of the pebbles. The floor also served to lay objects on for glazing, as the superfluous glaze had run down and spread over the pebbles as a thin wash of green." (*Tell el Amarna*, p. 26.)

Dr. Petrie found fritting-pans, measuring about 10 inches across and 3 inches deep; also cylindrical jars, 7 inches diameter and 5 inches high, that he assumed to have been used as supports upon which the pans of frit composition rested whilst in the melting-kiln. Even the potters' working moulds were found; and whereas from Memphis, Thebes, Gurob, etc., only a few dozens of moulds were obtained, he brought nearly 5000 from Tell el Amarna. These moulds are rough pats of baked coarse clay, with the impression on one side, and marks of the palm of the hand on the back. Many of these moulds, and a considerable number of glazed plaques for inlaying in walls, are now located in the Ashmolean Museum, Oxford; and there are others in the Edwards Museum, University College, London.

This remarkable discovery of highly decorative glazed tiles explains much that the earlier discoverers of the later work in the palace of Rameses III. at Tell el Yehûdîyeh found very perplexing. It may also be worth noting that the reign of Amenhotep IV. (Akhenaten) coincides with a period of early civilisation and art in Greece (1400 B.C.).

The plate of coloured illustrations (Plate V.) represent five fragments of enamelled tiles from Tell el Amarna, date B.C. 1370, kindly lent by Professor W. M. Flinders Petrie, D.C.L., F.R.S., for the purpose of copying and illustration in this volume, also some pieces from Gurob.

A, is a fragment of an enamelled tile of semi-vitreous granular vesicular white body, ornamented in choice shades of green and brown, with a few touches of dull-toned slate-blue enamel.

B, is a piece of an inlaid enamelled tile, the surface or field being of lovely tinted green enamel, decorated simply with lines of brown, while inlaid in cleanly cut out circles of the surface have been white porcelain daisies, conventional in form, with yellow centres. One only of these daisies remained in position, thus explaining the object of the empty depressions. And it is not a little surprising to find one's own child bringing in from the garden a living flower of daisy type, as nearly as possible identical in form and colour with this ancient Egyptian representation. Mr. John Ward, F.S.A., of Belfast, tells me he has seen these porcelain daisies in collections, by fifties, and has picked up several himself at Tell el Amarna. They appear to have been used in very large numbers; and a little consideration will show that the form of the daisy is peculiarly amenable to decorative uses. They also appear on the enamelled bricks of Babylon.

C, is a similar fragment of similar composition, having a beautiful green enamelled surface, with lines in brown enamel, representing the stems and leaves of the daisy plants. This piece also has several circles cleanly cut out for inlaying, and most probably these were originally inlaid with porcelain daisies.

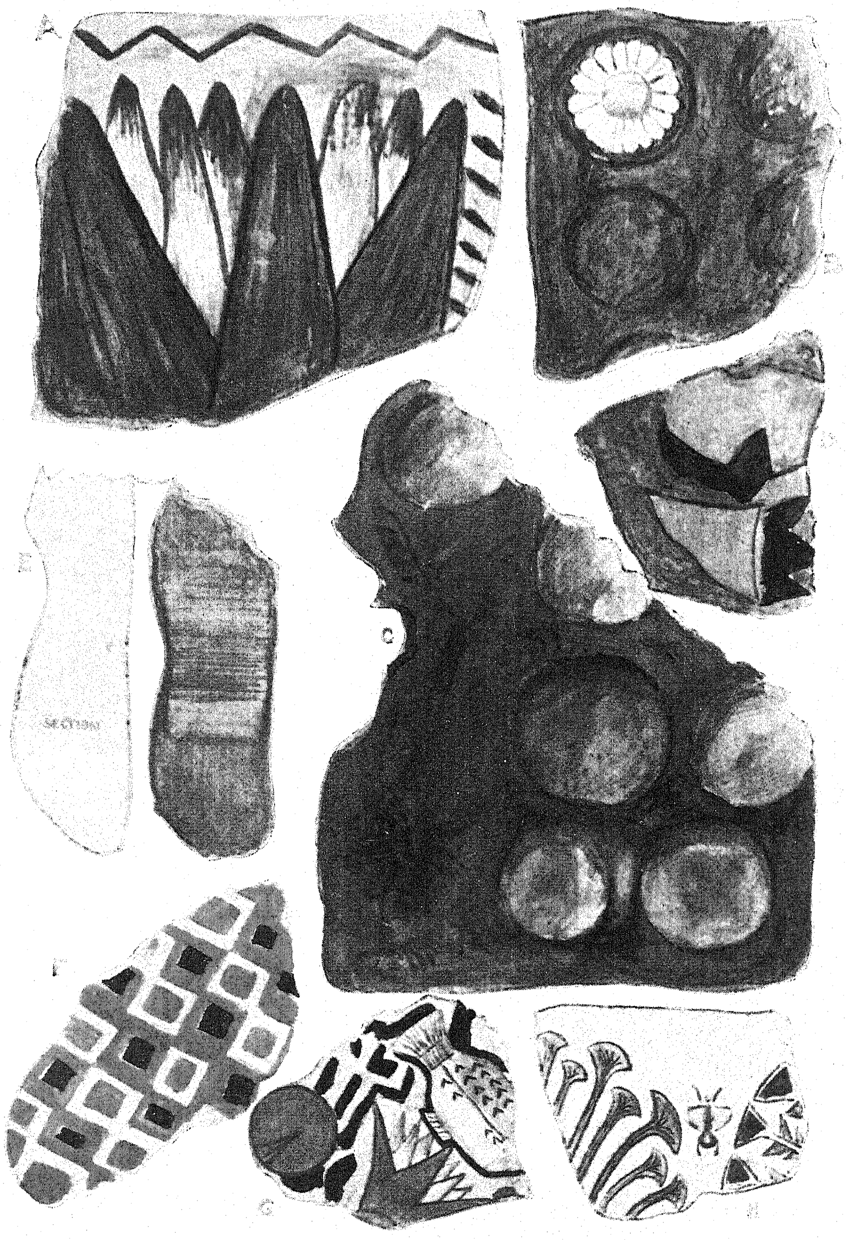
D, is a small portion of a tile inlaid with yellow or buff coloured body or paste, having incised cuts around the inlays describing leaves and flowers, enamelled with rich yellow enamel, with green leaves, outlined with brown.

E, is a fragment of enamelled moulding, of identically similar semi-vitreous, semi-friable, granular vesicular white body to that of the tiles, very thinly enamelled on the front only, with very pretty yellow green enamel.

F, represents a fragment of inlaid red glazed ware, kindly lent to me by Dr. Petrie, which, he says, originally formed part of a cushion in a figure scene. The pattern is chequered in yellow enamel lines, the zigzags forming the rhomboid spaces or trellised work. Alternate rows of centres are inlaid with a slate-blue coloured enamel composition.

G, is a fragment of an inlaying tile from Gurob (18th dynasty); enamel

Pl. V.



Fragments of Enamelled Tiles from TELL-EL-AMARNA and GUROB.
(By permission of Professor W. M. Flinders Petrie, D.C.L., F.R.S.)

inlays on a white tile. The body is white, siliceous, and rather friable, about a quarter inch thick. Part is inlaid deeply with slate-blue ceramic paste or body, and part is glazed or enamelled with turquoise. Outlines, shadings, and markings are in brown enamel applied by brush. Other parts and the back is white-glazed, and all is very skilfully executed and skilfully burned.

H, is another really choice fragment of inlaying tile from Gurob, said by Dr. Petrie to be of 18th dynasty. This tile is only an eighth of an inch thick. Body almost white, siliceous, and slightly friable. Apparently this has been covered with glaze while in the clay state, and then deep inlays cut out very cleverly and vitreous inlays inserted, thick and deep; these had contracted during burning: the yellow-green tint harmonising most sweetly with the rich red and cream colour and the brown outlines, altogether forms a highly artistic and suggestive design.

Besides those just mentioned, Dr. Petrie has a fragment of glazed brick or of a large slab from Tell el Amarna. The body is apparently chiefly composed of silica sand, bound with a little diffused frit, producing a remarkably firm body, with sandy vesicular fracture. Upon the body there appears to have first been applied a thin wash of vitreous siliceous engobe. Superimposed on this on three faces is another engobe, nearly one-eighth of an inch thick, of lavender or puce coloured dense but siliceous paste. Through this lavender-coloured engobe a white inlay has been cut down for and inserted. Then the whole three faces glazed with turquoise glaze, which appears turquoise on the white inlay and dark slate-blue on the main portion.

Sundry other pieces of glazed pottery were also made during the 18th dynasty for decorative purposes, such as representations of bunches of grapes of dark blue glazed porcelain, with perforated tenons for attaching to woodwork. Also highly finished plaques or small slabs, with relief patterns of sacred birds, and eyes and hands, elaborated in white enamel with brown outlines and shadings.

To this period—18th dynasty—is assigned the magnificent turquoise-blue glazed sceptre from the temple of Nubt, presented to the South Kensington Museum by H. M. Kennard, Esq. It is a most beautiful object, about 9 feet high, richly inscribed. (See *V. and A. M. Catalogue*, p. 29.)

"Of the houses in which the Egyptians lived at this period," writes Dr. Budge, "we know little." . . . . "Of the furniture which was used in such houses we know a great deal, thanks to the tombs at Thebes, from which have been recovered so many beautiful examples of tables, chairs, couches, etc., often inlaid with ebony, ivory, and cedar wood, and the fact should always be remembered that by far the greater number of objects of this class which are found in the museums of Europe are the product of the 18th dynasty, and belong to no later period." (*History of Egypt*, vol. ii. p. 178, Kegan.)

In connection with the 19th dynasty, Mr. John Ward, F.S.A., has very kindly permitted the illustration of two fragments of encaustic inlaid or figured cartouche tile of Seti II., B.C. 1189. One of the fragments is shown in Mr. Ward's *Sacred Beetle*, plate vi.; this portion was found at Karnak some years ago. When there again early in 1902 he luckily obtained a fragment of another very similar tile, which, singularly enough, contained the other portion of the design, and so completed and explained both.

The body of these tile fragments is white, semi-vitreous, and remarkably durable; the inlay is a slate-blue coloured ceramic composition; and the whole is glazed with a hard and nearly transparent glaze. The general appearance is not unlike Wedgwood Jasper ware. An incised mark at the back seems to be the maker's initial, or some significant sign. Mr. Ward thinks there must have been hundreds of such tiles in a small shrine erected by Seti at Karnak, but has never seen any other of the same encaustic tiles in any collection.

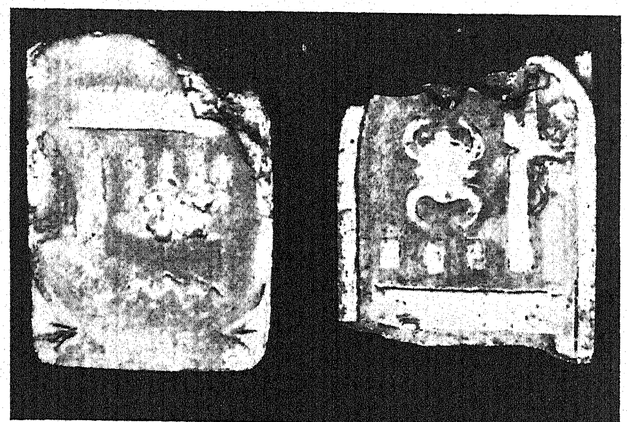


FIG. 13.—Cartouche tiles, $\frac{3}{4}$ in. thick, from Karnak (Thebes). Seti II., 19th dynasty, 1189 B.C. (J.W. Colln.)

Professor Petrie, however, appears to have a circular inlaid cartouche tile of similar kind, but with the hieroglyphics of Amenhotep III., 1400 B.C.

The next point of interest is Tell el Yehûdîyeh. Ceramic antiquities from this locality are usually attributed to the time of Rameses III., about B.C. 1170, but this monarch by repute sometimes destroyed ancient monuments to provide material for new buildings of his own, so that in case of some of these things there is room for doubt as to when and where they were manufactured.

It may not be out of place here to remark—as Mr. Ward kindly pointed out—that we are now dealing with a period when the Egyptians had already possessed a knowledge of glazing for more than three thousand years; the recent discoveries at Abydos demonstrating that glazed pottery and tiles were made during the time of the 1st dynasty.

From Dr. Budge we learn that this powerful monarch rebuilt and repaired many ancient temples of Egypt, and that his name has been found on their remains in many places between the Mediterranean and Wadi Halfa.

Edouard Naville, in his report to the Egypt Exploration Fund on "The Mound of the Jew," mentions that in the great Harris papyrus all the buildings erected by Rameses III. are described at great length, and that amongst these reference is made to "the abode of Rameses in the house of Ra, north of On": this is assumed to have been a palace for his own use when coming periodically to worship at Heliopolis, the centre of Egyptian sun-worship. But Rameses died and was gathered unto his fathers, and in course of time came the hosts of the Persians under cruel Cambyses, who destroyed the city of Heliopolis, leaving the deserted and desolate palace of the great Pharaoh to the bats.

A thousand years later some Jews, seeking refuge and protection in Egypt, by chance came upon the ruins of On, and begged and obtained permission to live there. There they dwelt and multiplied, and lived and died, until in A.D. 70 the Romans persecuted, plundered, and expelled them.

Hence the coincidence of Tell el Yehûdîyeh (the Mound of the Jew) with the ancient site of Rameses' palace, north of On. The site is about 16 miles N.N.E. of Cairo, but the writer understands from Mr. Ward that it is only accessible at low Nile. And even when the travellers get there, it seems that the site is about all that remains to be seen. Professor Maspero says the temple was rifled at the beginning of the 19th century, and specimens of glazed tiles brought thence have been in the Louvre since the time of Champollion, and all that remained of the building and its decoration was demolished a few years ago by dealers in antiquities. (*Egypt. Archæ.*, p. 269, Grevel.) In 1870 the mound was examined by Dr. Brugsch, Mr. Chesters, and Mr. Eaton, who found there the remains of a chamber lined with enamelled tiles, of the time of Rameses III. "But the discovery," writes Edouard Naville, "has been fatal to the mound. . . . . When I arrived at Tell el Yahoodieh, in the winter of 1887, the chamber of Ramseses III. had entirely disappeared. . . . . Not only the chamber, but nearly all the monuments indicated either by Brugsch or by Professor Lewis have vanished." (*The Mound of the Jew*, vol. vii. pp. 6–7, E.E. Fund.)

Naville tells us that Dr. Brugsch's attention had originally been directed to the place by some fine enamelled tiles and inlaid ornaments which he had purchased from a dealer at Shibeen-el-Kanater. Brugsch excavated and found traces of an alabaster pavement, and a considerable number of enamelled and porcelain tiles. He brought back from the mound 3600 disks of various sizes and a great number of tiles, more or less broken, bearing either flower ornaments, or birds, animals, and portraits; also many with hieroglyphic inscriptions, giving the names and titles of Rameses III.

Thus it comes about that just as we have now to seek for the remains of Heliopolis or On, not so much in Egypt, as in the ruins of ancient Rome, and the public squares and museums of European and American cities, in like

manner relics of the palace of Rameses III. must now be sought, not at Tell el Yehûdîyeh, but at Cairo, Berlin, London, Aberdeen, etc.

So long ago as A.D. 1873 Dr. S. Birch wrote, "In the temple of Rameses III. . . . . the walls . . . . were revetted with porcelain tiles containing the legends and conquests of the monarch. Some of the tiles consisted of long rectangular slips with the hieroglyphs incused and inlaid with pastes. . . . . The backgrounds of these tiles were generally blue. . . . . Another class of tiles representing Asiatic and negro prisoners conquered by the same king are of entirely novel character, and resemble modern Palissy ware. . . . . Among the Asiatic tribes were the Khita, the Rubu, the Tahemu, and others. Both black and copper-coloured negroes appear." (*Hist. Ancient Pottery*, p. 49.)

FIG. 14.—Relief tile from Tell el Yehûdîyeh. (*By permission of Grevel & Co.*)

Professor G. Maspero says, "The pictorial subjects, instead of being sculptured according to custom, were of a kind of mosaic, made with almost equal parts of stone tesseræ and glazed ware. The most frequent item in the scheme of decoration was a roundel moulded of a sandy frit, coated with blue or grey slip, upon which is a cream-coloured rosette. Some of these rosettes are framed in geometrical designs or spider-web patterns; some represent open flowers. The central boss is in relief; the petals and tracery are encrusted in the mass. These roundels, which are of various diameters, ranging from three-eighths of an inch to four inches, were fixed to the wall by means of a very fine cement. They were used to form many different designs, as scrolls, foliage, and parallel fillets, such as may be seen on the foot of an altar and the base of a column preserved in the Cairo Museum. . . . . The details, either incised or modelled upon the clay before firing, were afterwards painted with such colours as might be suitable. The lotus flowers and leaves which were carried along the bottom of the walls or the length of the cornices were, on the contrary, made up of independent pieces, each colour being a separate morsel cut to fit exactly into the pieces by which it was surrounded." (*Manual of Egyptian Archæology*, p. 269, Grevel & Co.)

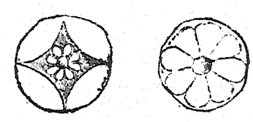


FIG. 15.—Roundel inlay tiles from Tell el Yehûdîyeh. (*By permission of Grevel & Co.*)

A piece of enamelled tile from Tell el Yehûdîyeh, corresponding to one of these sections (fig. 16), may also be seen in the museum at Stoke-upon-Trent.

Professor Maspero states that Mariette (a French Egyptologist who visited this site about thirty-four years ago) recovered, though with great difficulty, some of the more important fragments, such as those upon which the name of Rameses III. was identified, and which thus dates the building. Among these were fragments of tile ornamented with birds or bats (fig. 17). A

fragment of similar design, kindly lent to the writer by Dr. W. M. Flinders Petrie, showed the possibility of highly effective ornamentation by this kind of enamelled tile; the bat or bird was painted in relief with thick opaque white enamel; the eye, beak, ear, etc. outlined in dark brown; and Dr. Petrie stated that the field was originally filled up level with bright greenish cement.

Patiently copied and elaborately coloured illustrations of enamelled tiles from Tell el Yehûdîyeh are given in Birch's *History of Ancient Pottery*, and in vol. vii. part 2 of the *Transactions of the Society of Biblical Archæology*, the latter being accompanied by a detailed description by Professor Hayter Lewis, who was much concerned to account for such a sudden outburst of decorative ceramic art, and laboured to explain in some plausible way how it came about, not knowing, as we now know—thanks to Dr. Petrie—that equally artistic enamelled tiles were employed in the days of Akhenaten, 1400 B.C., if indeed some of the relics of Tell el Yehûdîyeh are not themselves spoils from Tell el Amarna.

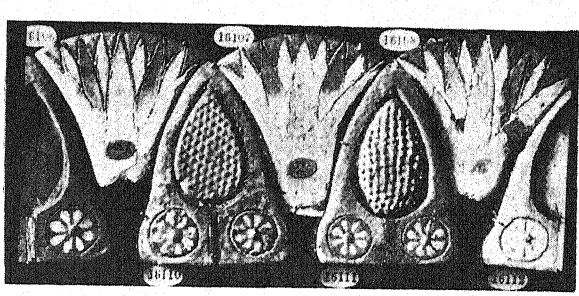


FIG. 16.—Enamelled tilework—fruit and lotus design—from Tell el Yehûdîyeh; now in British Museum. (*Illustrated by permission of Dr. E. A. Wallis Budge, Litt.D.*)

Mr. Henry Wallis makes sparse reference to Egyptian glazed tiles, but his comments on the antiquities from Tell el Yehûdîyeh could scarcely be in terms of higher praise:—"With the advent of the third Rameses in the 20th dynasty a marked revival of the art took place. This is clearly discernible in the series of wall tiles which decorated the king's palace at Tell el Yahoudieh. All the resources of the art were employed on these splendid plaques. We find therein bas-relief inlaying and a palette of the widest range; nothing can be imagined in ceramic art more masterly than the modelling of the human figures and the animal forms; the lions especially are of sculpturesque dignity. The types of the different nationalities (prisoners of war) are seized with an accuracy which may be termed scientific; their costumes display a wealth of imaginative details worked out in schemes of colour so resplendent and harmonious as to be the delight of all artists. Some of the greatest triumphs of decorative art have been achieved in the direction of wall tiles; yet it would

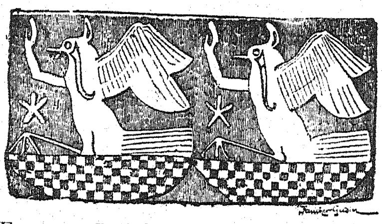


FIG. 17.—Relief tile. Tell el Yehûdîyeh. (*By permission of Grevel & Co.*)

be difficult to name a series of any period or country on which have been lavished such high artistic qualities as on those which ornamented the palace of Rameses III. on the Delta of the Nile." (*Egyptian Ceramic Art*, Macgregor Colln., p. , Quaritch.)

Another Egyptian tile, kindly lent for examination and illustration in this volume by Professor Petrie, is one found on the site of Koptos, and attributed to the 20th dynasty. This prettily tinted little tile measures 2⅝ inches by 2⅝ inches by ⅝ inch or thereabout, and has chamfered edges, which cause the face to be somewhat larger than the back. There is no tenon.

The body is of porous light buff-coloured substance, yet still frit-bound and slightly vesicular. The inlay is of severe design, with a distinctly Assyrian motif; the inlay measures slightly less than 2 inches by 2 inches, and is most cleverly and artistically applied in a delightfully pretty tint of dark silver-grey or pale lavender vitreous enamel or paste. This specimen Dr. Petrie justly prizes as a precious one; nevertheless he kindly favoured me with the loan of it for purposes of inspection and illustration.

FIG. 18.—Tile from Koptos. (W.M.F.P. Colln.) (*By permission of Dr. Flinders Petrie, F.R.S.*)

The 26th dynasty, which commenced under Psametik I., B.C. 670, and terminated at the conquest by the Persians, B.C. 525, is reputed to have been conspicuous for its encouragement of art and trade. Its capital, Sais, about 60 miles from Alexandria, was formerly recognizable by a few mounds, but Mr. John Ward informs me that these have now been carried off for fertilizing purposes; and the Nile has risen so much that the site of the ancient city is often unapproachable by land, and any ruins must be waterlogged and 20 feet below. In *Pyramids and Progress* he writes:—"Considering the elaborate description of the extent of Sais given by Herodotus, one would have expected great remains . . . . but Mariette's researches gave but a poor result. The very site of the ancient buildings could not be discovered, and none of the great monuments."

During the Ptolemaic period—B.C. 323 to B.C. 30—Dr. Budge leads us to infer that the court and the army were Greeks and spoke the Greek language, yet they governed the Egyptians with great consideration and tact, and under these monarchs Egypt became as great and as rich as ever. The Ptolemies were a long line, and Dr. Budge declares Cleopatra VII. to have been by far the cleverest of all their descendants (*Hist. Egypt.*, vol. viii., preface, Kegan). But during all this time practically no reference to the use of glazed tiles appears in history, coinciding remarkably with the

Enamelled tiles or faience from Tell el Yehûdîyeh. (B.M.)

(*By permission of Dr. E. A. Wallis Budge, LL.D., etc., Keeper of the Assyrian and Egyptian Antiquities, British Museum.*)

collateral absence of such architectural luxuries in Greece, Phœnicia, and Judea.

Summarizing, then, it will be observed that five principal examples of the decorative use of glazed tilework by the ancient Egyptians have been identified, namely:—

1. In temples of the 1st dynasty at Abydos.
2. In a chamber of the step pyramid of Sakkarah, 3rd dynasty.
3. At Gurob, during the 18th dynasty.
4. In the palace of Amenhotep IV. at Tell el Amarna, 18th dynasty.
5. In the palace of Rameses III. at Tell el Yehûdîyeh, 20th dynasty.

Antiquities and relics from these sites may be seen in the new museum at Kasr-en-Nil, Cairo (opened 15th November 1903), whither the treasures of the old Gizeh Museum have been removed; also in a great number of national, local, and private collections in Europe and America.

Grecian.—Unsurpassed if not unsurpassable in sculpture, bronzes, and die-sinking, raising almost every craft they attempted to the level of an exemplary fine art, the Greeks of the fifth century B.C. yet derived their first artistic impulses from some still more ancient civilizations.

Sir George Birdwood, in his instructive address at Kidsgrove on 22nd June 1899, remarked that the Greeks "were, until very recently, supposed to have received the first inspiration of their arts from Egypt and anterior Asia; and one of the greatest services rendered by the potter to the history of art has been to prove, within the present generation, that, while Hellenic art certainly received certain impulses and a variety of decorative motives from both Mesopotamia and Egypt, there existed in Greece, centuries before the Dorian invasion (*circa* B.C. 1100), a highly developed indigenous art, which, in the traditions it provided of the close study of nature and of refined technical methods, laid the solid foundations of the Hellenic art of Greece, as it began to assert its independent individuality between the eighth and seventh centuries, and reached its perfection in the fifth and fourth centuries B.C.; and that the influence of this pre-Hellenic art of Greece not only dominated the immigrant Hellenes, but asserted its influence over Europe, far beyond the limits of Greece, to the very shores of the Baltic Sea and the German Ocean. In 1868 Schliemann made his marvellous discoveries in the prehistoric mound at Hissarlik in the Troad, and in the prehistoric ruins at and about Mycenæ in the Argolid. These discoveries included not only figurines, but all sorts of objects of art, of which the most sensational were, of course, the jewellery of elaborately wrought gold. Schliemann thought he had broken into the treasuries of Priam and Atreus and laid bare the very bones of Agamemnon. But he had done something much more important in the elucidation of the history of European art, for his discoveries—confirmed as they were by the discovery of similar figurines . . . . in the neighbourhood of

Athens and, sporadically, all over Greece—demonstrated that an indigenous civilization, capable of the highest artistic achievements, had preceded the primitive Hellenic civilization of Greece, and that its beginnings must have extended back to the very verge of the neolithic night of Europe; and after it was suddenly blotted out by the Dorian invasion of Greece (*circa* B.C. 1100), the tradition of it still remained a living artistic force in Greece. . . . . This Mycenæan or, as it is now called, Ægean art culminated in the fifteenth century B.C. . . . . The jewellery is, as already said, wrought with the utmost skill, while the pottery, in the best-baked ware, is found fully developed in colour, glaze, and varnish. . . . . The recent excavation of the Acropolis, below the débris of the buildings re-erected on the sacred hill after the destruction of Athens by the Persians B.C. 520, led to the discovery of . . . . immense collections of the remains of primitive Hellenic art that had lain there buried and undisturbed for over two millenniums. After this date there was a rapid evolution of Hellenic art, the chronology of which, from first to last, is always to be most clearly and fully traced in the fictile wares." (*British Clayworker*, August 1899.)

The Parthenon at Athens, commenced about B.C. 447 and completed about B.C. 438, may be taken as a representative structure upon which Hellenic-Greek artists and architects lavished their best. Its costly embellishments have often been described, and, though almost entirely of marble, Sir W. B. Richmond tells us it was coloured from top to toe. Yet with all its structural and sculptural display, no ornamental tiles or ceramic plaques are found upon its walls or floors.

In like manner no mention of decorative faience appears in descriptions of either the temple of Apollo at Phigaleia, nor the great temple of Artemis (Diana) at Ephesus, each of which were magnificent erections embodying superb architectural and artistic skill. (See *Guide to Greek and Roman Antiquities in the British Museum.*)

Terracotta they had certainly—their vases in this material still form patterns for the civilized world; and of their constructional terracotta, Mr. Joseph Mayer, F.S.A., of Liverpool, has written:—"Enamelling was not then known, but the exceeding beauty of their moulded tiles and cornices excites our admiration to this day." (*History of the Art of Pottery.*)

Mr. John Ward, F.S.A., in his *Rambles in Sicily*, graphically describes the ruins of a Græco-Roman theatre—the most perfect in the world—at Taormina. It is, for the most part, an old Grecian structure, occupying an outlying hilly site on an unsubmerged portion of the ancient Greek city Naxos. A portion of this theatre, Mr. Ward tells us, is built of red terracotta; but not a word about glazed tiles is vouchsafed.

It would seem almost incredible that the Greeks of the fifth century B.C., with all their love of art, should from choice or caprice neglect colour-effects

such as glazed ceramics afforded; and yet their intercommunication with Persia at this period would necessarily bring some of them within touch of Babylon and Susa.

It would be a libel to say they were deficient in colour-sense. The only alternative, therefore, seems to be to suppose that, with all their skill in terra-cotta, they yet had not acquired greater proficiency in the preparation of glazes and ceramic enamels than the simple varnish and black enamel they made such effective use of upon vases.

Roman.—Long before Rome rose to power an early Greek civilization spread to Italy; and after the partial eclipse of this civilization in the mother-country of Greece itself by reason of the barbaric Dorian invasion, this hardy offspring retained its power in Italy; so that even until about 800 B.C., Professor Petrie asserts, the arts stood high in Northern Italy.

The Etruscans, whose name is so often on our lips, yet of whom we know so little, are believed to have entered Italy from the north, probably before the beginning of written history. As their territory lay near Rome, they became, when the Romans gathered strength, the early objects of jealousy and attack, and ultimately, about B.C. 285, were politically extinguished.

In course of time Imperial Rome became an example of the most prodigal architectural magnificence, grand vistas in the city and river-scapes by the Tiber lending their aid in the general effect. Superluxurious buildings became a fad or fancy of patrician and plebeian alike, the interior embellishment of which was equally lavish and extravagant; for, as a conquering nation, the Romans wrested spoils from many lands, and had these gems of ornament reconstructed in the imperial city. To the decorative tile-maker, the most striking feature of ancient Rome and her many colonies is their mosaic pavements. The elaboration and gorgeousness of many of these are astonishing, and their durability is demonstrated by hundreds of examples nearly 1700 years old.

The enormous proportions of the Colosseum enabled it to very largely resist burning and pillage by the Goths and Huns, and it is said to have remained tolerably complete down to the eighth century A.D. But thenceforward for hundreds of years it suffered despoilation by successive Roman princes and popes, who used it as a kind of quarry from whence to draw material for the erection of palaces for themselves. During this period probably the mosaics, with which the walls of the Colosseum are said to have been covered, were taken away: anyhow, none of them appear to have come down to our times.

The Pantheon, one of the very few ancient buildings of Rome still standing in a splendid state of preservation, originally built by Agrippa, B.C. 27, seems to have no mosaics and no glazed tilework. It was built of Roman concrete faced with bricks and covered with Greek marble. The roof was

divided into sunken coffers and gold gilt. The floor is covered with Egyptian granite and porphyry and Numidian marble.

According to Professor Reynaud, the principal examples of ancient mosaic floors now open for inspection in or near the imperial city are the following:—

(*a*) At the Capitoline Museum, a mosaic known as Pliny's doves, found in Hadrian's Villa, near Tivoli, and which was seen and described by Pliny as a Roman copy of the work by Sosus of Pergamus.

By the courteous permission of the Board of Education an illustration of this (fig. 19) is shown, being reproduced from Dr. Wollaston's series of drawings in the Art Library, South Kensington.

Mr. Guy Wilfrid Hayler, in a communication to the Society of Arts, speaks of this example as the work of "early Greeks"; and states that "it is composed entirely of cubes of marble without any admixture of coloured glass, thus showing that it is some of the earliest work of its kind." (*Jour. Soc. of Arts*, 15th February 1901, p. 209.)

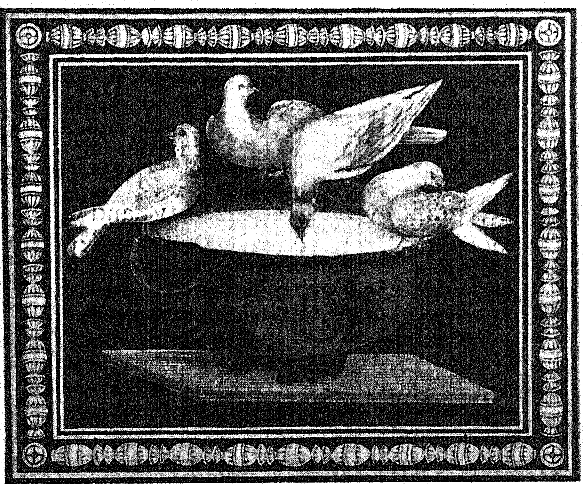


FIG. 19.—Pliny's doves. Mosaic.

(*b*) At the House of Livia (House paternal of Germanicus) the floor of the tablinum or sitting-room is covered by fragments of mosaic showing a Greek pattern of exquisite design.

(*c*) At Hadrian's Villa, once an extensive and magnificent ancient Roman pleasure-ground, near Tivoli, a number of rooms in that part called Ospedale have the floors covered with mosaic of white and black colours. Here, too, are wall mosaics (see fig. 20). The one illustrated is entitled "Summer," and is, by permission, reproduced from Dr. Wollaston's drawing in South Kensington Museum.

(*d*) At the Lateran Museum may be seen a splendid and very large mosaic, which was removed from the baths of Caracalla. It represents gladiators and fighters.

(*e*) At the Vatican, in the round hall, is to be seen the mosaic floor found at Otricoli, representing sea-monsters; in the cabinet, the mosaic representing masks found at Hadrian's Villa; and in the hall of animals, beautiful slabs of mosaic representing cattle, also from Hadrian's Villa.

(*f*) At the Borghese Museum, in the saloon a mosaic floor found near Torre Nuova representing gladiatorial and wild-beast combats.

The ancient Roman method of forming such floors seems to have been, first of all, to construct a thick firm foundation of rough concrete; or in cases where heating chambers (hypocausts) were below, to cover these in with large tiles resting upon the brick pillars; then upon these tiles a layer of small bricks, set herring-bone style, with a thin stratum of lime and chalk cement superimposed; upon this were fixed the very small blocks, or tesseræ, of marble, precious stones, glasses of various colours, and baked-earth fragments, artistically arranged according to the design, and set in cement or mastic of some kind. These floors sometimes consisted of only two or three colours, such as black and white marble and red tile. At other times they prove to have been gorgeously elaborate pictures, constructed with infinite labour, skill, and expense,—the scenes depicted including horsemen, charioteers, birds, flowers, etc., of extreme beauty of form and colour, albeit what we now see being only the wrecks remaining after 1400 years or more of decay, despoilation, restoration, and removals.

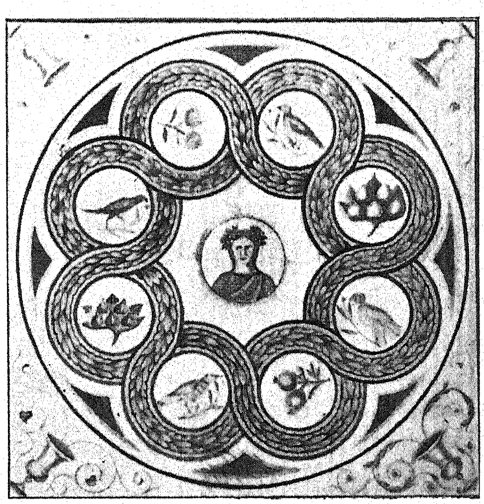


FIG. 20.—Wall mosaic. From Hadrian's Villa.

It would seem, however, that we cannot justly apportion all the praise of this exhibition of artistic skill to the Roman people themselves. Mr. Mayer asserts that "the pottery of Rome, like all the other arts of that military people, was borrowed. They had no style, although there is a very marked manner about the productions made under their dominion." All their works of art appear in reality to have been of Greek design and frequently of Greek execution.

Langenbeck emphasizes a feature of these mosaic pavements, which, from the ceramist's point of view, is of importance; namely, that in the floors of Roman villas preserved in France, Germany, and England, the marble portions were worn through in the days of their use, whilst the tesseræ of baked clay, forming the reds, buffs, and browns of the floors, and used in conjunction with the marble in the same floors, are hardly touched to this day. (*British Clay-worker*, July 1899, p. 104.)

Professor Reynaud remarks that as long as the ancient Roman mosaics

are protected by a roof they keep well fixed, but when from any cause they become exposed to heat and cold the work splits. For this reason, in summer the mosaic pavements in Rome are covered with mortar.

The ancient Romans made use of tiles for many other purposes than floors, as, for instance, in the construction of drains, hypocausts, walls, and roofs, the colour being mostly red. Brongniart refers to lead-glazed ware of the third century A.D., but neither this nor the Samian ware appear to have been applied to architectural purposes by the Romans. (*Traité des Arts Céramique*, vol. ii. p. 106.)

With regard to Pompeii, Mr. Dawson, in his *Great Cities of Italy*, graphically describes its present condition thus:—"Pompeii itself is the most amazing spectacle in all Italy. Here is a Roman town, precisely as it was 1800 years ago, miraculously preserved for our inspection. Here are the deep ruts in the street worn by innumerable chariot wheels . . . . the shops of the winesellers and manufacturers of mosaic, with the signs of their respective trades still above their doors. . . . . The mosaics which adorned the floors and thresholds of the houses, and sometimes covered the walls, are of incomparable excellence. . . . . One represents a comic scene, another depicts with admirable realism various kinds of fish, all of which are caught to this day in the Bay of Naples. In these mosaics, jasper, agate, and porphyry are employed." Finally Mr. Dawson asks, "If a little second-rate town was the centre of so rare an art, what was the grandeur that was Rome?" (*Great Cities of Italy.*) Respecting the destruction of Pompeii, Dr. Dyer has recorded that about A.D. 74 Vesuvius afforded unmistakable signs of evil intentions, several buildings being overthrown. On 24th August A.D. 79, without other warning, a vast column of smoke was ejected from the mountain, followed by thin light ashes, then small heated stones and stifling gases. Soon streams of dense mud poured irresistibly down the mountain and over the city, those who had taken refuge in buildings and cellars being closed in for ever. Thus, amid many pathetic incidents, Pompeii disappeared; how pathetic, how horribly pathetic, can be imagined by reading Lieutenant Scott's description of the recent eruption of Mont Pelée, and the woes caused thereby in the town and harbour of St. Pierre (Martinique). (See *Strand Magazine*, September 1902.)

Centuries passed away, and with them the power and glory of Imperial Rome and the very recollection of Pompeii. Fifteen hundred years later labourers cutting a canal discovered evidences on the site, but not until A.D. 1763 was it placed beyond doubt that long-lost Pompeii had been found.

Fortunately, the nature of the overburden facilitated excavations, and under judicious control and direction marvellous examples of ancient arts and customs were opened to view; an enormous collection of articles gradually accumulating, most of which may now be seen in the Museum at Naples.

Many Pompeian mosaic floors have, worked into the pattern near the entrance door, the inscription SALVE, meaning *Welcome*; others have CAVE CANEM, *i.e.*, *Beware of the dog*. A phenomenally fine mosaic, which originally formed the floor of the dining-hall of a house excavated at Pompeii in the year 1829, called the House of Faun, may be seen in the Naples Museum. It is a pictorial representation of a historical subject worked out with greatest skill. When first discovered Italian critics were enraptured with it; the vividness and harmony of the colours, the apparent transparency of the atmosphere, and the good figure-drawing were astonishing. Professor Quaranta wrote of it thus:—"The extreme delicacy of this work in marble far surpasses the celebrated mosaic of Palestrina. . . . . It is impossible to describe the consummate skill with which so many figures are arranged and grouped in this confined space, or the truth and correctness of the drawing, the distribution of light and shade, the effect of the colours, and scrupulous attention to the minutest accessories. Michael Angelo and Raffaelle might have been proud of the dying horseman." In this mosaic are represented twelve horses, a large war-chariot, and twenty-two persons, more than half the natural size, without reckoning those that were on the left side, which is almost totally destroyed. (*Pict. Gall. Arts*, p. 180.)

FIG. 21.—Floor in the House of Faun.

In the entrance or vestibule of the Grosvenor Museum, Chester, will be found some very large coloured drawings of Pompeian mosaics which convey some idea of the excellence of the work.

There is something very pathetic in the more recent discovery that Pompeii was not the first place to be overwhelmed by Vesuvius. Under the title *An Earlier Pompeii*, the *Illustrated London News* of 13th June 1903 says:—"It would appear that Vesuvius began its work as a conservator of antiquity earlier than the memorable year A.D. 79. During the excavations in the valley of the Sarno, near San Marzano, in Campania, some most interesting antiquities have come to light. These had been covered by a volcanic deposit about 6 feet thick, which points to an eruption of Vesuvius which must have taken place certainly not earlier than the seventh century before Christ. The relics include a Greek burying-place, archaic Italian

tombs, and various bronzes and terracottas. Near the same site, but of course not covered by the volcanic deposit of the earlier eruption, is a Roman house of the time of Augustus. The house was, indeed, built upon the bed of cinders and pumice-stone beneath which the tombs, bronzes, and terracottas were discovered. The dwelling escaped the catastrophe of A.D. 79, for Pliny tells us that a strong wind blew the ashes in the opposite direction from the valley of the Sarno. The latest researches have brought to light a village of the earliest inhabitants of that region." A sheet of illustrations accompanies the above comments, but there is no mention of tiles.

Dr. Wollaston's series of coloured drawings of ancient mosaics, which he bequeathed to the Science and Art Department at South Kensington, reveal the fact that mosaic pavements were used in all the principal colonies and dominions of the Romans. In France examples of mosaics have been discovered at Arles, Autun, Avignon, Bergheim, Besançon, Bevoy, Dijon, Lyons, Nantes, Nîmes, Orânge, Poligny, and Vienne. One dug up at Lyons was composed of small cubes of marble, interspersed in some places with pastes of different colours. In this the whole details of the circus games were represented. It comprised no fewer than eight chariots, which appeared as if they had started together, but some having fallen, the horses and charioteers were represented as having also fallen. Spectators are depicted as having surrounded the scene and to have been regarding it with eager interest.

In Spain numbers of examples have been found, Dr. Wollaston's drawings including mosaics from Italica, Rielves, and Tarragona. Towards the close of the eighteenth century a remarkable specimen was discovered near Seville, at a small depth below the surface of the ground. It was 40 feet long by 30 feet wide, and contained, in the centre, a representation of the circus games of the ancients, while on three sides were compartments containing figures of the muses, etc. (*Pict. Gall. Arts*, p. .) According to Rev. S. Manning, Italica was a Roman-Spanish city, founded by Scipio and adorned with sumptuous edifices by Adrian. It was situated at the foot of olive-covered hills, five miles from Seville. Like most of the ancient remains in Spain, it has served as a quarry for builders of succeeding times. Its massive stones became material for a neighbouring convent, and for a breakwater in the Guadalquivir. In the vaults of the ruined amphitheatre, which once served as dens for animals and captives, beggars now lurk to beset the visitor with entreaties for alms. All else is silent as the grave, where once stood a wealthy city, the birthplace and home of Emperors. (*Spanish Pictures*, p. 156, R.T S.)

Romano-British.—Even before the invasion of Britain by the Romans, the condition of the inhabitants seems to have been far above that of barbarism. Intercourse with Phœnicians, Gauls, Belgians, and possibly with the

Greeks of Massilia (Marseilles), had already raised the people out of savagery. Coins were struck, and beautiful enamelled work is mentioned as having been made at this early date. But during the 400 years or so of Roman occupation of England, civilization of a still higher degree spread over the central and southern districts. At this time the fertility of the island was turned to such good account that 800 vessels are said to have been at one time engaged in conveying corn to Roman cities in Germany. Walled towns were built, great main roads formed, aqueducts and baths constructed, and comforts and luxuries greatly increased. According to Gibbins, there were no less than fifty-nine cities in Britain in the middle of the third century A.D., and a population of 10,000,000. (*Industrial History of England.*)

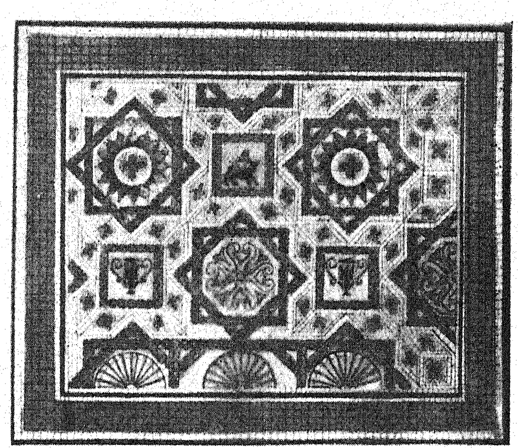


FIG. 22.—Mosaic pavement found near the Bank of England, 1805 (now in the British Museum). (*From Dr. Wollaston's drawing in the Art Library, South Kensington, by permission.*)

FIG. 23. — Mosaic pavement, Leadenhall Street. (*From Dr. Wollaston's drawing, South Kensington Museum Art Library, by permission.*)

In the twelfth century, Wright assures us that England was covered with the remains of Roman ruined towns and villas standing aboveground. It is not surprising, therefore, to find, here and there throughout the whole length and breadth of the land, remains of Roman erections, the most striking of which are the mosaic pavements.

Londinum (London) in Roman times was, apparently, not a capital city, but chiefly a place of trade. It was burnt in the great revolt under Boadicea; but from its ashes rose again and became prosperous. Many beautiful examples of artistic Roman floors of villas have been discovered. In 1803 one was unearthed opposite East India House in

Leadenhall Street, at a depth of 9 feet 6 inches below the street. The central device was a figure of Bacchus, reclining on the back of a tiger, a purple and green mantle falling from his right shoulder. The square border surrounding it consisted of two belts of ornate design. Beyond this a margin of 5 feet broad was formed of plain red tiles, each an inch square. Great ingenuity was evinced in forming this floor, some twenty separate tints of different materials being introduced, the major part consisting of baked earths; the more brilliant colours of green and purple being of glass. (*Pict. Gall. Arts.*)

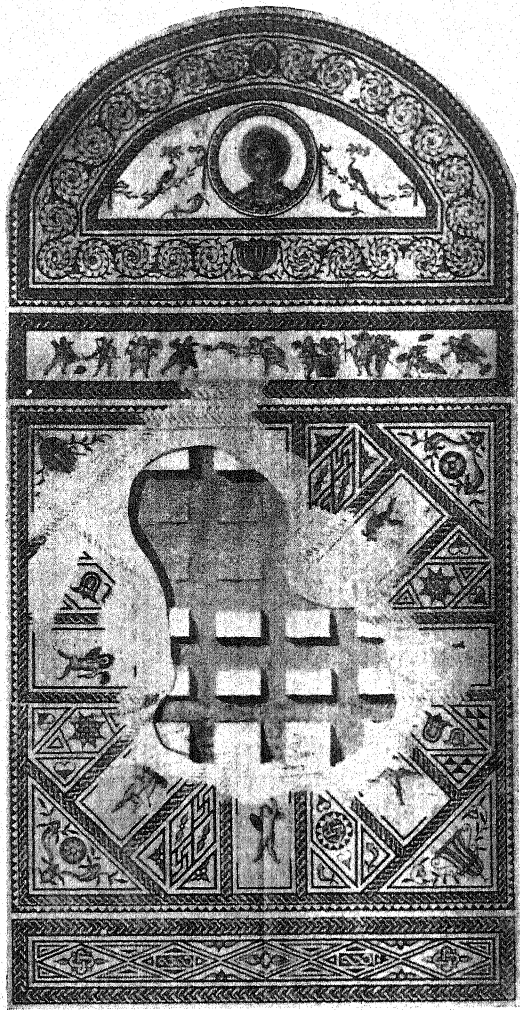
Cannon Street, Holborn Hill, Crutched Friars, Broad Street, Fenchurch Street, Eastcheap, Lothbury, Threadneedle Street, and the vicinity of the Bank of England have all furnished similar antiquities; and how many have been destroyed, and how many more remain undiscovered, we may never know. Examples are preserved in the British Museum and the Guildhall Museum. The illustrations, figs. 22 and 23, are from Dr. Wollaston's drawings, by permission.

Camulodunum (Colchester).—Professor A. H. Church describes this as the first regular military colony formed during the governorship of Ostorius, the captor of Caractacus. Several ancient tessellated pavements are preserved in the Colchester Castle Museum, and Mr. Alfred Bennett Bamford, curator, states that particulars of these have appeared in the *Trans. Essex Archæological Society*, vol. iv. p. 53, and vol. iii. new series, p. 207. And there are descriptions of other pavements found in the locality, but not removed, vol. v. p. 154, vol. ii. new series, p. 189, and vol. iii. new series, p. 140—all illustrated except the one mentioned in vol. v.

Northleigh (Oxfordshire).—Remains of a Roman pavement still exist here, but I have been unable to obtain a description. Formerly there were also remains of a pavement at Stonesfield, which the Right Hon. Viscount Dillon very kindly informs me is engraved in *Vetusta Monumenta*, but he believes that the pavement itself has been long destroyed.

Bignor (Sussex) furnishes remarkable examples of ancient mosaics. From *Archæologia*, vol. xviii. p. 203, we learn that:—"Roman remains were first noticed here in 1811, when a mosaic pavement was discovered about a quarter of a mile east of the church." Then follow minute descriptions of its materials and design, and of other pavements discovered. In the following year, Samuel Lysons, F.R.S., most carefully investigated these remains, and prepared elaborate drawings and descriptions, which are reproduced and placed on record at great length. The most artistically attractive floor is described by Lysons thus:—"About 30 feet north of the room marked I in the plan, a piece of very fine mosaic work was discovered, a little below the bottom of the ditch on the north side of the field. . . . Careful investigation in 1813 of this pavement (see K on plan) showed that it was a parallelogram of 22 feet by 19 feet 10 inches, with a semicircular recess at the north end, 10 feet in diameter,

making the whole length 32 feet. . . . . The design of the pavement was remarkably rich and its subject particularly interesting; it consisted of one large compartment, 13 feet 6 inches square, between two narrow oblong ones, with a fourth approaching to a semicircle, occupying the recess at the north end. The square enclosed an octagon, within which had been eight small oblong compartments meeting towards the centre, where they must have formed an inner octagon, none of which remained. Each of the small oblong compartments was 2 feet 9 inches by 16 inches; two of them were entire, containing figures of cupids or genii. . . . . Two of the triangular divisions at the four corners of the square contained figures of urns, with fruit and foliage; the other two were filled with cornucopia and foliage. The several divisions of the large square compartment were formed by a guilloche, of the same alternate colours as those in the other pavements. The oblong compartment on the north side, the square one, was 13 feet 7 inches long and 2 feet 6 inches wide, including the border formed of a doubly braided guilloche: it contained twelve figures of cupids or genii habited as gladiators, and exhibiting a very complete representation of the costumes of the *retiarii* and *secutores*. . . . . The semicircular division at the north end of the pavement is formed by a guilloche, within which is an elegant scroll of foliage proceeding from a goblet; and enclosing a circular compartment with a fret border, within which is represented a female head, ornamented



H. Wright.] [*Photo.*

FIG. 24.—Mosaic pavement, Bignor.

with a chaplet of flowers; tresses of hair appear on the shoulders, which are naked. The most remarkable circumstance attending this subject is that the head is surrounded with a *nimbus*, like that of a Christian saint, of a light-blue colour . . . . On each side of the circular compartment are cornucopi and festoons of foliage, with two birds, one on each side, which seem to have been designed for pheasants. . . . . The ornaments and general style of the mosaic work at Bignor bear a striking resemblance to those of the pavements discovered at Pompeii, which could not have been of a later date than the reign of Titus. . . . . The Bignor pavements differ from any yet discovered in Britain, and have the appearance of much greater antiquity. The figures, too, are composed of much better materials, and are much better drawn and executed than those which appear in other works of the kind so frequently found in this island." (*Archæologia*, vol. xviii.)

Dr. Wollaston's series include six drawings from Bignor.

Calleva (Silchester).—About ten miles south-west of Reading the site of a large Romano-British town is being slowly explored. It comprises about 100 acres of what is now arable and pasture land in the parish of Silchester, enclosed by the remains of a Roman wall nearly two miles in circumference. In the illustrated report of the excavations during the years 1895 and 1898 are coloured drawings by W. H. St. John Hope, Esq., M.A., and George G. Fox, Esq., M.A., representing both red-tile tesseræ and artistic marble mosaics. A portion of one of these drawings we are courteously permitted to reproduce. (Fig. 25.)

Referring to the pavements, the 1895 Report states that:—"The first impression conveyed to the eye by these floor mosaics is that of a predominance of black and white in the designs. But a second glance will show a variety of colouring not perceived at the first moment. In the pavements of chambers 22 and 27 of House No. 1 (Insula XIV.), besides the invariable black and white, we have a scarlet and purple red, a greenish and orange yellow, a bluish, a greenish, and a brownish grey. The materials of which these floors are composed are, with very few exceptions, all of native stones, or Purbeck marble; the principal exception being in the composition of the bright-red tesseræ, which are always of brick, whether employed in the larger form as a ground for the finer work, or as smaller cubes in the finer work itself. The tesseræ of which the finer mosaics are composed are on the average ½-inch square."

On the coloured plan of House No. 1 (Insula XIV.), in the 1895 Report, no less than twenty-two floors, corridors, etc., show evidence of having been paved with red-tile tesseræ; and those floors where mosaics are employed generally have wide margins of red-tile tesseræ all round the mosaic.

From the 1898 Report we gather that the black tesseræ were sandy limestone; the white tesseræ, hard chalk; and the dull orange were supposed to be

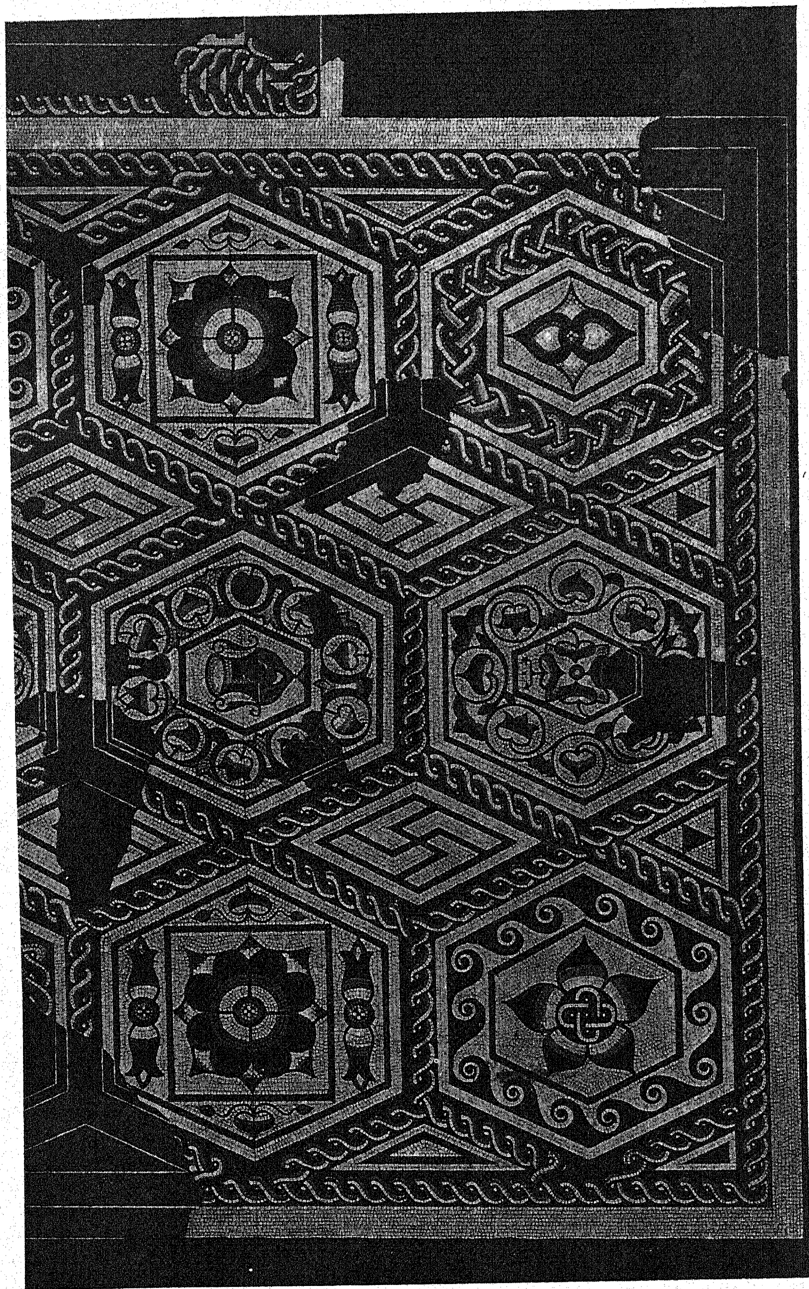


FIG. 25.—Mosaic pavement at Silchester. (*By permission of W. H. St. John Hope, Esq., F.S.A.*)

a burnt stone. The dark greenish-grey tesseræ were always of Purbeck marble; the reds always of brick, but two qualities were used—one orange in colour, the other the usual red.

Durnovaria (Dorchester).—Mr. H. J. Moule, in his *Dorchester Antiquities*, writes:—"Durnovaria seems to have abounded in these handsome floors." The most remarkable find appears to have been made in 1858, when three floors of a Roman house were uncovered at the east end of the grounds of Dorchester Gaol. In other words, this house was almost certainly within the precincts of Dorchester Castle; and this, again, very probably took the place of the Roman Governor's house. In 1862 and 1875 other finds occurred; and in 1900 large portions of a floor were struck during preparations for the new Devon and Cornwall Bank in South Street. The largest Roman floor found in or near Dorchester was discovered in 1899, in the back-garden of a new house in Olga Road. As to Roman coins, Mr. Moule says the place, after all these centuries of casual findings, is still full of them.

With regard to a Roman pavement found at Somerleigh Court, Mr. Moule writes:—"The sight of a mosaic floor as the Romans left it is a rare event. Therefore no time was lost in going to Somerleigh Court. There, at the bottom of a trench, 5 feet or more deep, half-covered with earth, could be seen bits of the floor, dim-looking enough. But Mr. Tite flushed away the loose earth with a pailful of water. Then almost flashed on the site the bright tessellation, striking in colour, lovely in design. . . . . It is a sight of beauty . . . . a sight full of emotion." (*Dorchester Antiquities.*)

Aquæ Solis (Bath).—The Roman roads from Calleva and Lindum to Ilchester crossed in the neighbourhood of Bath, and upon Hampton Downs there is the ancient borough or camp. In the second century A.D., it is supposed that the site was changed on account of the proximity of the mineral-water springs, which were even then becoming famous, and a new city, *Aquæ Solis*, was erected where Bath now stands. Here the Romans built palatial baths, which were rediscovered in 1754. Three large Roman villas have been discovered in the Bath valley, and these, together with a few fragments of paving, of altars, and of tombs, in conjunction with the baths themselves, form the only remaining local relics. (See *Bath as a Health Resort*, Bath Corporation.) The *Illustrated London News* of 11th November 1902, however, gives illustrations on p. 697 of some more recent discoveries in the neighbourhood of Bath; and on p. 690 these are referred to thus:—"In a garden a few yards to the north of Box Church, about 5 miles from Bath, some excellent remains of a Roman villa have, during the last three months, been excavated by the Wiltshire Archæological Society. . . . . Mr. H. Bell, of Cleeve House, Melksham, undertook to bear the whole expense. . . . . The mosaic pavement was wrought in five colours—white, blue, yellow, red, and purple."

Isca Silurum (Caerleon)—The history of Caerleon during Roman times

so far, appears to be undiscovered. It is supposed to have been founded A.D. 70, and was the seat of the second Augustan legion, and capital of the Roman province of Britannia Secunda. Taking into consideration the many times Caerleon has been attacked and plundered since the days of the Romans, it is no wonder that comparatively little remains. Still, pavements have been found here. So long ago as A.D. 1693, Edward Lhwyd wrote:—"These ancient pavements are not buried so deep in this county as they are in the churchyard at Woodchester in Gloucestershire, for that lies about three foot depth; this at Kaer Lion lay no deeper than the ploughshare." (Camden's *Britannia.*)

In 1862 Mr. J. E. Lee, F.S.A., of the Priory, Caerleon, wrote an illustrated catalogue of the antiquities in the Caerleon Museum, which by the kindness of Mr. Alfred E. Hudd, F.S.A., of Clifton, I have been able to examine. It mentions and illustrates inscribed stones, altars, coffins, red-glazed ware, lamps, vases, bricks, moulded cornices, tiles, mosaic pavements, fibulæ, nails, hooks, chains, bells, spears, coins, spoons, etc., etc., besides numerous mediæval relics. And there is a coloured plate of a mosaic floor at Caerwent, simple and unpretentious in design and colouring, but very pretty.

Venta Silurum (Caerwent).—Systematic excavations were begun on this site by a committee of the Clifton Antiquarian Club in August 1899. Up to January 1901 about three acres had been explored, and amongst other buildings traced was one containing upward of forty apartments, wherein were found remains of tessellated pavements, baths, etc. On all four sides of the peristyle of another house, an ambulatory was found of an average width of 9 feet, paved with tesseræ of brick. Wherever mosaic pavements were found in the interiors they appear to have been of the kind distinguished as *Opus Signinum, i.e.*, the simplest kind of Roman mosaic. An illustration of one of these is on plate xxv., *Isca Silurum*, by J. E. Lee, F.S.A.; and coloured reproductions of two floors are shown on plates x. and xi., *Archæologia*, vol. lviii.

Brislington, near Bristol.—In December 1899 remains of a Roman villa were discovered, in a field on the north side of the present Bath road, about half a mile beyond Arno's Vale Cemetery, the actual discovery taking place when workmen were cutting trenches for the drainage of a new road. Before measures for the preservation of the tessellated floors could be taken, they had been cut through; but sufficient plans and drawings of the remains were secured by the exertions of the Clifton Antiquarian Club and the Bristol Museum Committee, to enable Mr. W. R. Barker, J.P., the chairman of the Museum Committee, to form a very succinct and interesting description, which is now published (price one shilling).

From this it appears that the pavements were found near the surface in an unprotected condition; and owing to the concrete foundation having

partially decayed, different parts of the pavements were found at irregular levels, and created difficulty in their removal to the museum.

Two pavements are figured in the published account of the discovery. These, by careful consideration of portions secured, are drawn out as completely as possible; and as Mr. W. R. Barker has very kindly consented to their reproduction in this volume (see Plates VII. and VIII.), a lengthy letterpress description is uncalled for.

Pavement No. 1 (Plate VII.) is a simple but pleasing geometrical design, in which the prevailing colours are red, white, and blue, with some tesseræ of brown and grey.

Pavement No. 2.—In this case much had been destroyed by violence or time, but, by a happy circumstance, the centre, to which all the rest was subordinate, had been wonderfully preserved. A beautifully coloured drawing of this centre was made by Mrs. Flora Bush, before the pavement was disturbed (Plate VIII.), and eventually the centre was successfully removed to the museum in one block.

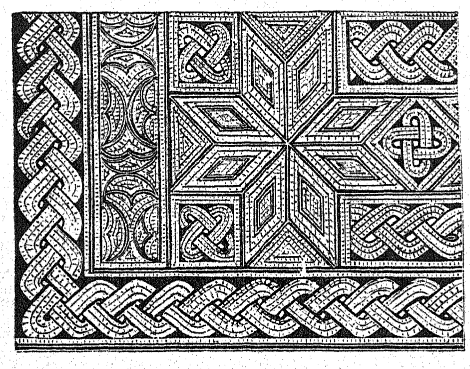
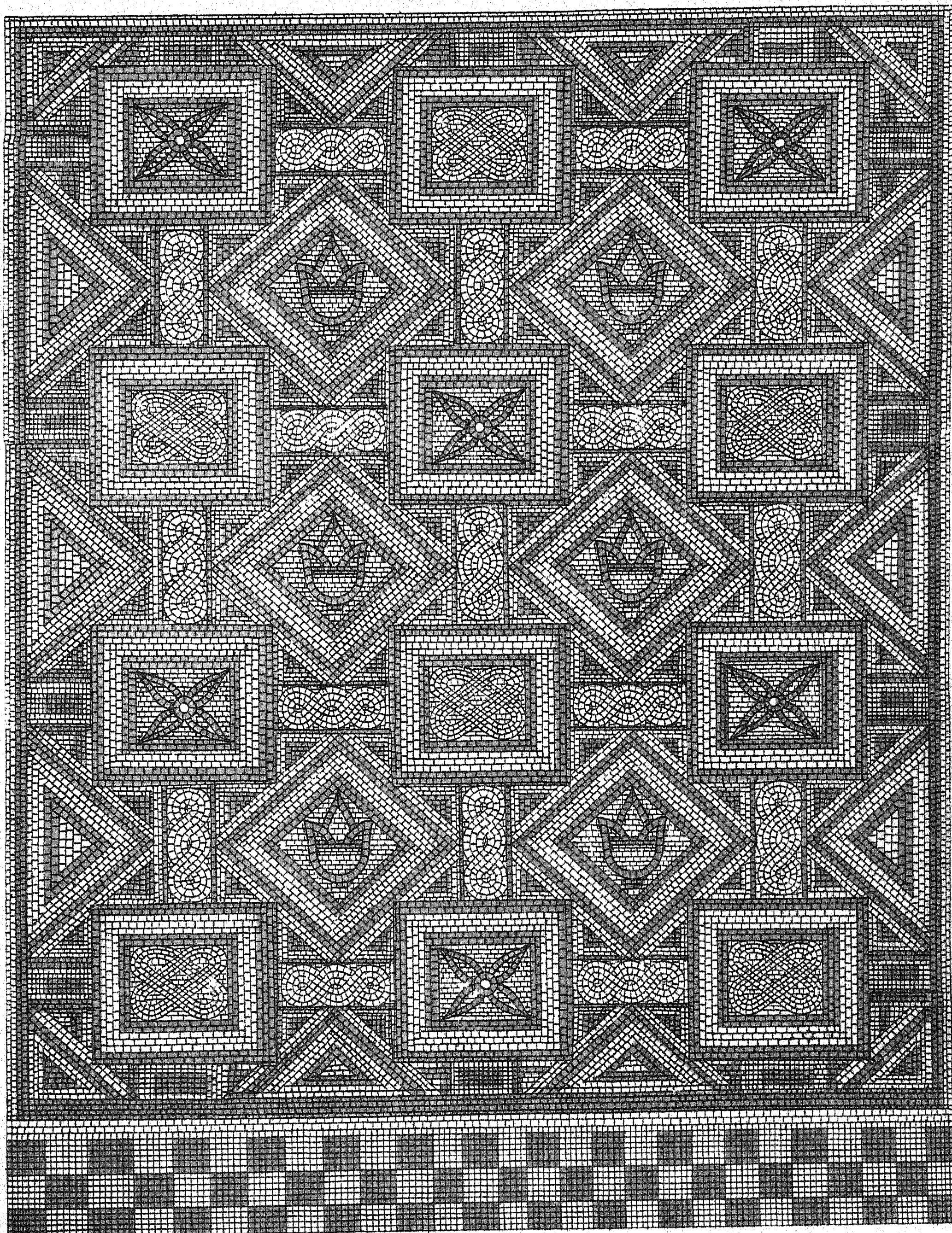


FIG. 26.—Mosaic found at Cirencester. (From *Cassell's Technical Educator*, vol. iii. p. 201.)

Several other interesting antiquities and relics were found on the same site, and are illustrated in the Bristol Museum publication about the Roman villa at Brislington.

Corinium (Cirencester).—Professor A. H. Church, M.A., F.R.S., in an interesting pamphlet on the Corinium Museum, mentions a very great variety of tiles and other Roman relics found in that district. Respecting the pavements he writes:—"The two fine mosaic pavements which occupy the greater part of the floor of the museum were discovered in a Roman villa in Dyer Street, Cirencester, in the year 1849, during drainage operations. . . . . Both pavements are of high quality, the larger one . . . . being of singular merit in design and excellent in execution. . . . ." Professor Church describes these floors in detail; and mentions others that have been found in the same neighbourhood. One had a walnut tree growing above it.

Woodchester, or *Woodmanchester*, near Stroud, Gloucestershire.—Underneath the quiet churchyard of this modest village, for centuries, lay the remains of one of the largest and finest mosaic pavements of Romano-British times ever discovered in England. Through the kindness of the rector, Rev. Frederick Smith, an illustrated pamphlet has been furnished describing this wonderful floor. Even in A.D. 1695 Woodchester was famous for its "tessariack work of painted beasts and flowers . . . in the churchyard."



LAVARS & C° LITH. BROAD ST BRISTOL.

PAVEMENT No. 1. Complete design.

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In 1779 Rudder wrote:—"Many coffins are placed upon the pavement, but it has been broken through at the request of some families who desired to have their friends interred at greater depth." In 1783 part of it was destroyed by exposure to wet and frost; and some years afterwards a portion of the scroll-work was presented to the British Museum by Lysons. Lysons examined it very carefully, 1793–1795, and discovered the foundations of a palatial residence, and published a monograph about it in 1797.

The "famous tessariack" proved to be the floor of the principal hall or ATRIUM, and measured 48 feet 10 inches square, the central part being formed in a circle 25 feet diameter, enclosed within a square frame, so to speak, of twenty-four compartments, each of intricate design and colouring. Within the braided guilloche is a broad circular band containing representations of animals, each about 4 feet in length. Originally there were twelve of these, separated from each other by mosaic representations of small trees set in a white background. Another, but much-damaged portion contained representations of birds, and, by report, another contained pictures of fish and sea-monsters.

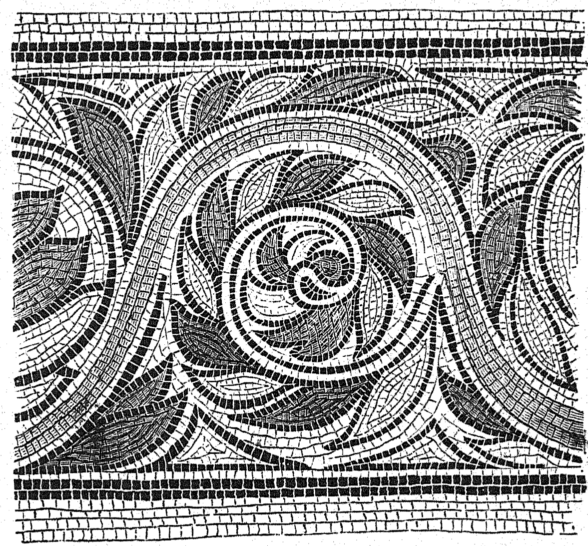


FIG. 27.—Mosaic from Woodchester. (*Cassells' Technical Educator*, vol. iii. p. 201.)

Beecham of Cirencester made an elaborate coloured drawing of this magnificent floor, and published lithographed copies of it many years ago.

Altogether Lysons is said to have ascertained the dimensions of sixty-five rooms, and three large courts—one 90 feet square, another 150 feet square; also evidences of other rooms—the whole covering an area of at least 550 feet by 300 feet. From its extent and evident magnificence, and its situation near three great Roman roads, this residence is supposed to have been that of the Proprætor, or chief military governor of the province, and may at times have been an imperial palace.

In the centre of the entrance-hall of the Museum of Practical Geology, Jermyn Street, London, is an example of Minton's modern British tessellated

pavement, from a design founded on the mosaics of Woodchester. (See *Handbook to the Jermyn Street Museum*, p. 110.)

Uriconium or *Viroconium* (Wroxeter).—Situated at the termination of the famous Watling Street, about six miles from Shrewsbury, are a few visible ruins of a once populous town, said to be 2000 years old. We learn from a publication by Thomas Wright, M.A., that one large structure appears to have been paved in its whole length (226 feet long by 30 feet wide) with small bricks, 3 inches by 1 inch, set in herring-bone style. In another part were found pavements in fine mosaics, evidently intended for roofed apartments, elegantly adorned within. One of the rooms adjoining the *old wall* (a remnant of solid Roman masonry still standing above-ground) had the interior surface of its walls ornamented with tessellated work, the floor having a plain pavement of small white marble tessellæ. In 1857 George Maw, Esq., F.G.S., of Broseley, made coloured drawings of several fragmentary portions of mosaics found at Uriconium, a reproduction of which we have been permitted to publish by the Committee of the Shrewsbury Free Library and Museum. Mr. Maw furnished the museum with some interesting comments on the nature of the materials used in forming the ancient mosaics of Uriconium, and these may be seen in wall-cases.

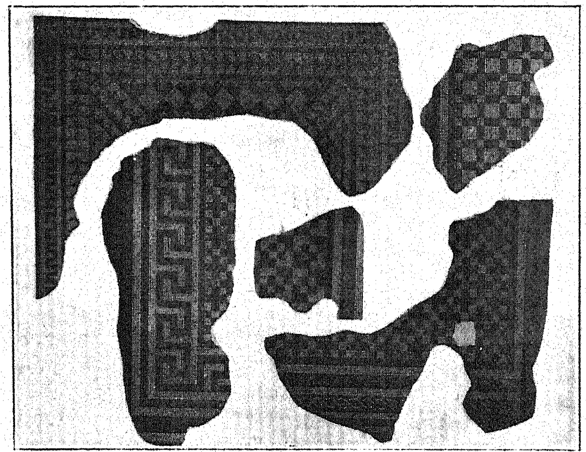
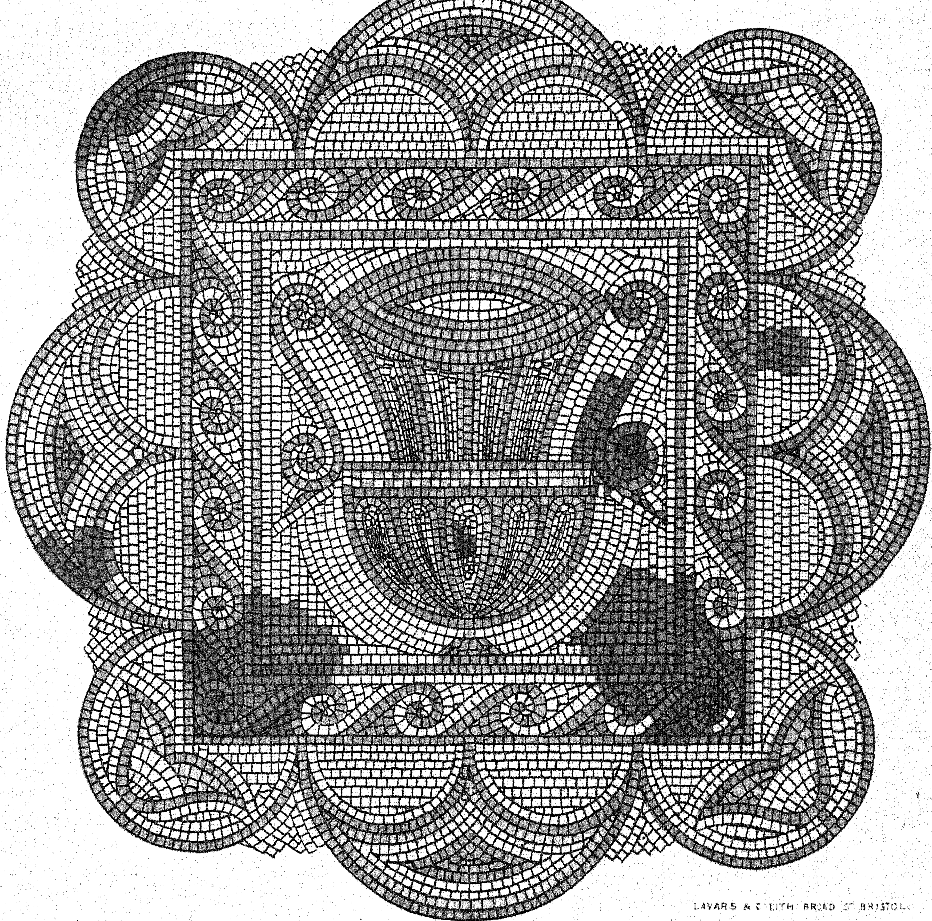


FIG. 28.—Fragments of mosaics from Uriconium. (*From a drawing by George Maw, Esq., by permission of the Shrewsbury Museum Committee.*)

In the same museum is an illustration of a beautiful mosaic pavement which was discovered at Lea Cross, near Pontesbury, some time earlier than A.D. 1793, for it is mentioned in the *Gentleman's Magazine* for 1793, part ii. p. 1144.

Deva (Chester).—This central stronghold, upon which five Roman roads converged, became a flourishing town; but the numberless vicissitudes it has subsequently experienced, together with the obliteration arising from continued occupation by man, has effectually reduced the traces of Roman life and customs to a vanishing point. What fragmentary relics have been preserved are now mostly housed in the Grosvenor Museum; the



CENTRE OF PAVEMENT No. 2.

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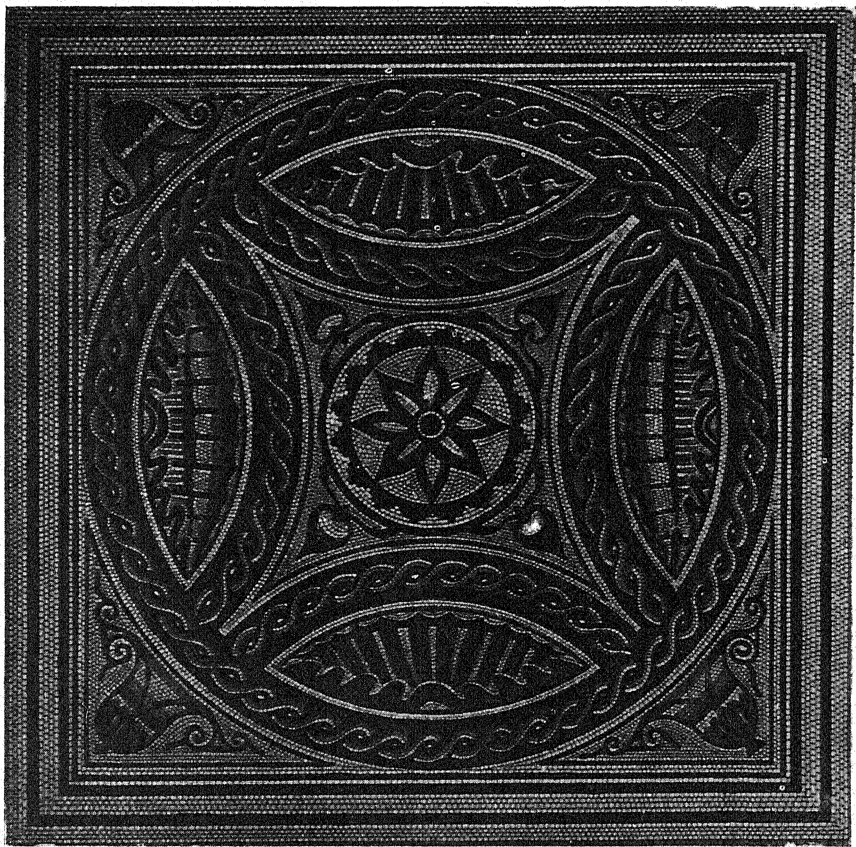

FIG. 29.—Centre design of mosaic pavement found at Lea Cross. (*From a coloured drawing in Shrewsbury Museum, by permission.*)

specimens of Roman flooring and tiles there are Nos. 187, 188, 189, 191, 200, 201, 202.

Rata Civitas Legionum (Leicester).—An interesting monograph by W. T. Tucker, Esq., F.G.S., of Loughborough, recently published in the *Reliquary*, furnishes the following:—"In the year 1832, whilst digging the foundations for some small houses, situated to the south-west of the Jewry wall in Leicester, a portion of an elaborate Roman pavement was discovered. At length the Town Council purchased the property, with the object of preserving the pavement *in situ*. During operations to make it accessible it was found the floor continued underneath the adjacent house. The owner was arranged with and the site fully explored, when an apparently square floor of about 23 feet was disclosed, together with its borders, and one piece of the original wall, bearing a face of ornamented plaster-work. It is quite impossible to describe the beauties of the geometrical patterns of which the floor is made up; suffice it to say its workmanship and colour-design are perfect. . . . . It was with considerable curiosity that I heard of the recent *find* near to St. Nicholas' Church. I at once visited the site, and was struck with the resemblance to the floor found in 1832. The floor appears to be a square of about 14 feet, and is divided into nine octagonal portions, the central one being occupied by the peacock. The borders are wide and are well shown in some places, the design is very elaborate, and the same heart-shaped pattern occurs as in the borders of the 1832 floor. It is 8 feet below the level of the present street, and about 50 yards from the south side of St. Nicholas' Church. A plainer floor of about 10 feet square was found in the position where one would expect the corridor to have been, and it has recently been found that the 1832 floor was provided with a similar corridor. It was claimed for the 1832 floor that such a magnificent and costly floor could only have been found in the principal villa, and that it must have been the site of the Prefect's house. But this new discovery, which is quite as beautiful and 400 yards away, would indicate that there were other villas equally worthy of being the house of the Prefect." (*Reliquary*.)

Lindum or *Lindum Colonia* (Lincoln).—In the City of Birmingham Reference Library there is a magnificent book of coloured engravings of Roman mosaics discovered mostly in Lincolnshire, drawn by W. Fowler, A.D. 1796–1802. Many of these are elaborate in the extreme. One, discovered near Winterton, A.D. 1797, is really of lovely design, apparently formed of red, black, and white tesseræ. Another floor, discovered about A.D. 1796, near Roxby, is also particularly fine; the colours are red, silver-grey, and white, and the design is made up of key-patterns, cables, lovers'-knots, and diamond shapes. The whole book is not only a monument of skill and patience in itself, but sets forth in a startling manner the marvellous works of the Romans. By permission of the chief librarian, Mr. A. Capel Shaw, a

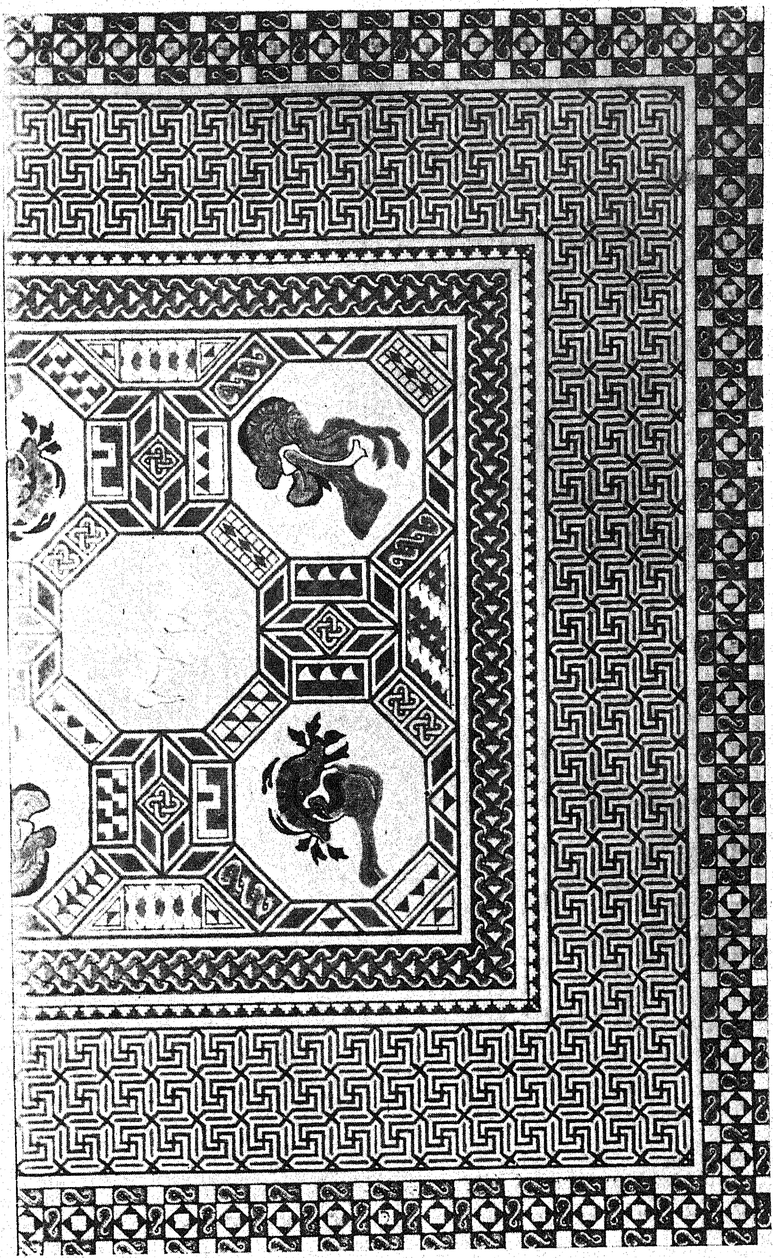

FIG. 30.—Mosaic pavement found at Micklegate Bar, York. (*After Fowler.*)
(*By permission of the City of Birmingham Free Library and Museum Committee.*)

reproduction of one of the wonderful drawings is illustrated in this volume.

Eburacum (York).—York having been continuously in occupation since Roman times, and subject to spoilation and overbuilding, cannot be expected to furnish more than a mere morsel of its ancient glory in mosaics. The Roman camp or capital here at first appears to have occupied only about sixty-five acres on the left bank of the Ouse, but this limited space seems soon to have become too small, and its population and buildings then occupied adjoining lands. Its importance may be inferred from the fact that the Roman Emperor Severus and his two sons, Caracalla and Geta, resided here a considerable time; indeed, according to history, the Emperor Severus died at York, A.D. 211, as also the Emperor Constantinus, A.D. 306. (See Smith's *History of England*, p. 5.)

In the grounds of the Yorkshire Philosophical Society a portion of the Roman wall and a Roman tower are still preserved. And among the antiquities in the museum is a Roman tessellated pavement, 14 feet 3 inches square, the pattern chiefly composed of labyrinthine fret, one centre representing the head of Medusa, and four others are symbolical of the seasons. This pavement was discovered in 1853 in Toft Green, about 14 feet below the present surface, with portions of another and the border of a third. In another room are two Roman pavements from neighbouring localities, the larger one from Oulston, near Easingwold, which was originally 36 feet long. Other pavements also have been discovered near York

When all are counted up, it would really be astonishing what a number of fine pavements have been found. Fowler's great book, and Lysons' *Reliquæ Britannico-Romano* and *Archæologia*, teem with descriptions and illustrations. Thus, under the very feet of our ancestors, unheeded for centuries, lay the patterns from which our most modern ceramic floors are really derived. An art lost to us for fifteen hundred years is being relearned and restored to practical utility.

Persian.—The art of the decorative tilemaker, whether originating with Babylonian or Egyptian, apparently spread eastward to Persia. Sir George Birdwood asserts most positively that: "In Persia the ancient art of glazing earthenware had come down in an almost unbroken tradition from the period of the greatness of Chaldæa." (*Jour. Soc. Arts*, 28th February 1879, p. 311.)

For a long time evidence of this was not too plentiful, because the ancient Persians left few records and few enduring buildings; their most extensive and populous, and by report their oldest city, Istakhr, is gone, with barely a trace remaining to tell of its existence. "All we know of Persia," writes Fergusson regretfully, "during her most brilliant period we learn only from her enemies. . . . Not one scrap of their literature remains to us, nor one native utterance, except it be the buildings of Persepolis and those in its

neighbourhood. These are all that Persia has left us of herself. Had they perished, and had other nations not transmitted to us her story, we might scarcely have known of her existence." (*Nineveh and Persepolis*, p. 87, Murray.) Subsequent excavations in Susiana certainly have yielded results of historical interest which we shall shortly notice, but the greater part of Persia proper is still barren and silent to the antiquary and archæologist in respect of its ancient glory. The explanation seems to be that the Persians built mostly of mud or sun-dried bricks, and this enabled the inclement climate effectively to reduce their "earth to earth."

In a very instructive paper on "Mud: a Material in Persian and Eastern

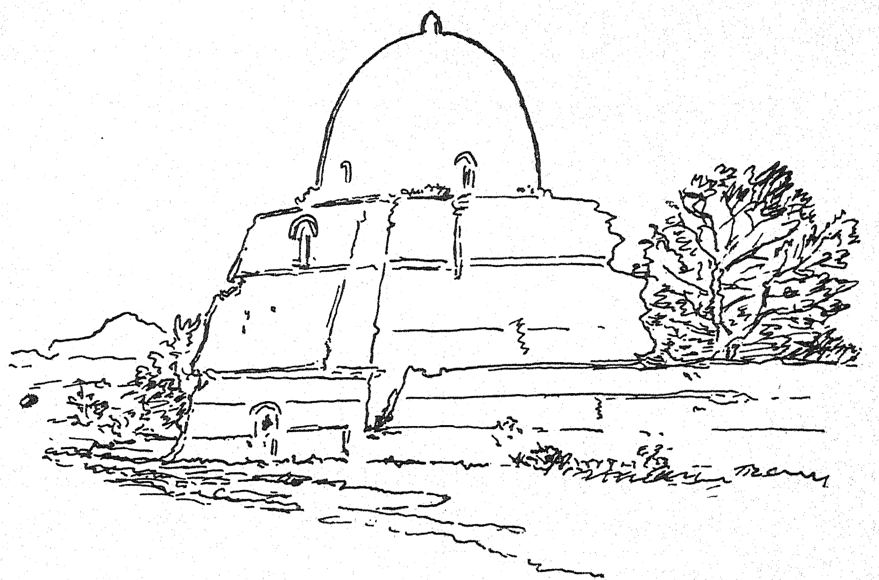

FIG. 31.—Tomb constructed of mud. (*By permission of the Royal Institute of British Architects.* See *Transactions R.I.B.A.*, vol. iii. N.S. p. 68.)

Architecture," read at the Society of Arts, 17th May 1892, Mr. W. Simpson, R.I., stated that "not only villages but large towns are built of mud or sun-dried bricks," and "over a large geographical space in the eastern world the building material of the present day is almost exclusively mud." And lest we should think that system of building belongs only to a rude condition of civilization, and only produces houses little better than hovels, Mr. Simpson asserts that "this manner of building was developed into a highly decorative style." (*Jour. Soc. Arts*, 3rd June 1892, p. 703.)

Even in the case of the ruins of Persepolis, which abound with marble pillars, doorways, stairs, and terraces, the astonishing feature about them is

an absence of walls. As Fergusson shows, if the walls had been of kiln-burnt bricks, chippings and fragments at least must have remained. No such tell-tales being found, he infers that the walls of Persepolis originally consisted of sun-dried bricks, partly ornamented with enamelled tiles after the manner of their neighbours. These tiles, he supposes, were either removed by the hand of man, or disintegrated *in situ*. Another supposition has been advanced by Vaux with reference to these ruins of Persepolis, namely, that hangings of some textile fabric may have been used to connect the pillars and doorways, and so form apartments or halls of audience. In support of this view he quotes Esther i. 5 and 6. (*History of Persia*, p. 116, S.P.C.K.) But Vaux assures us that "the oldest certain relic of Ancient Persia" is "the curious structure commonly called the *Tomb of Cyrus*. . . . This remarkable building stands in the middle of the plain of Murgháb, on a site usually identified with that of Pasargadæ, the capital of Persia in the time of Cyrus." Even this seems to have been so very thoroughly *restored* by order of Alexander the Great, that what now remains conveys the impression of Grecian rather than Persian architecture. The only point of interest in it for us is that there is no mention of decorative tiles within or without this structure. (*History of Persia*, pp. 87–90, S.P.C.K.)

Another important monument from which it is disappointing to learn so little is the inscribed rock of Behistán, which includes nearly 1000 lines of cuneiform character, and which those who formed it took great pains to render durable and inviolable. Vaux speaks of it as "the most valuable of all Achæmenian remains"; but he tells us sorrowfully that Sir H. C. Rawlinson has remarked that "we must be content for the most part to peruse a certain formula of invocation to Ormazd, and a certain empty parade of royal titles, recurring with a most wearisome and disappointing uniformity." (*Persia*, p. 96, S.P.C.K.) More tangible evidence, however, was eventually wrested, at great risk and cost, from this apparently barren field of archæological research: first, by W. K. Loftus, F.G.S., about 1852, whose perilous enterprises at Susa have been so graphically recorded in his *Chaldæa and Susiana*, and whose relatively small finds, including some fragments of enamelled bricks, were sent to the British Museum; and, secondly, by the remarkable discoveries of M. Dieulafoy in the same locality, subsequently. The superb specimens of ancient mural ceramics, dug up by the latter in 1885, were essentially composed of many small enamelled bricks formerly forming part of a frieze in the palace of Darius I. (521 to 485 B.C.) at Susa. The originals were safely transferred to the Louvre, and have since formed one of the wonders of that home of wonders, and the chief theme of many a eulogy of Ancient Persian art.

Mr. Clement Heaton, speaking at the Society of Arts (24th March 1891), described these examples as a "grand series of works in low relief and enamel

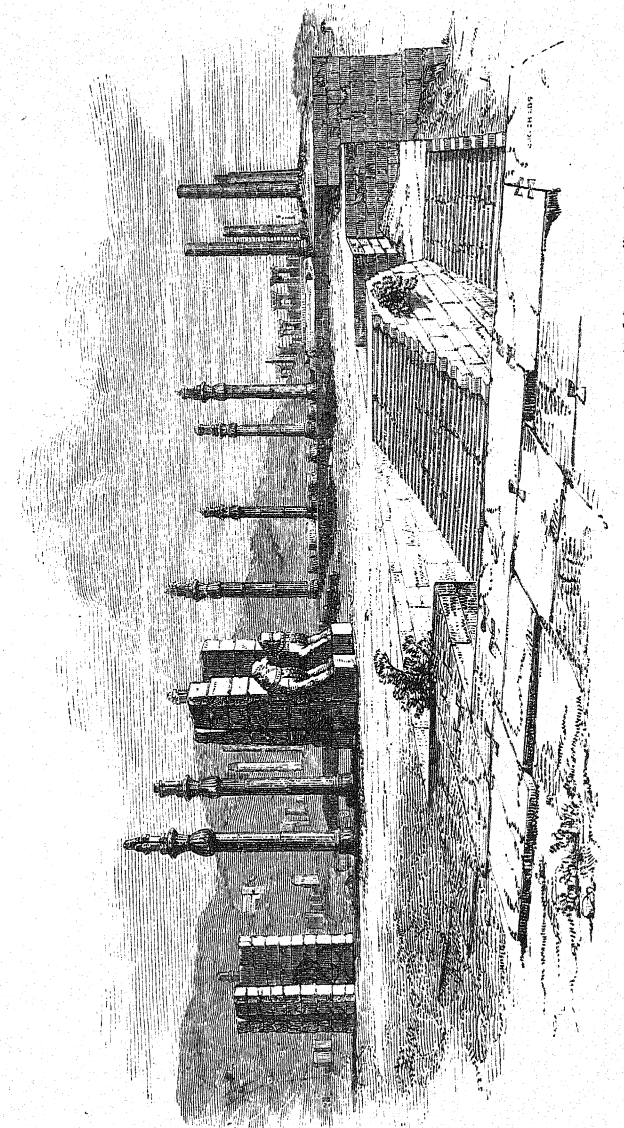

FIG. 32.—Ruins of Persepolis. (*From Fergusson's "Indian and Eastern Architecture," vol. i. p. 199. By permission of Mr. John Murray, London.*)

from the palaces of Darius and Artaxerxes Mnemon at Susa." "One of these friezes," he says, "is 12 yards long by 11 feet high, in perfect preservation, with a procession of archers in profile, and bands of ornament. Another is a frieze of lions with ornament above and below." The effect, he assures us, is one of striking beauty—a harmony of soft blues, greens, and yellows, with a little white and brown, the whole treatment being that of *cloisonné*, of which the outlines consist of "fillets of clay, separating the enamels and reflecting lines of light." (*Jour. Soc. Arts*, 3rd April 1891, p. 379.)

FIG. 33.—Portion of the "Archer Frieze," from a replica in coloured plaster-work, Victoria and Albert Museum. (*Illustration reprinted from "Arch. Review,"* April 1902, p. 117.)

This palace of Darius I. is said to have been destroyed by fire during the reign of Artaxerxes I. (465 to 425 B.C.), but the final destruction of the city of Susa by the Saracens, and its desertion, is assigned to a date shortly after A.D. 709, that being the latest date of the coins. Here then, at least, the Arabs had an opportunity of learning something of the wonderful ceramic decoration of Ancient Persia. One striking feature, however, cannot well have escaped the notice of the reader, namely, the remarkable similarity between these Susa friezes and those found recently by the German explorers at Babylon. The question at once presents itself: are these Ancient Persian enamelled brick-reliefs "spoils of war" from Babylon, or are they the work of artist Chaldean captives sent by Cyrus or Darius to Susiana? This would seem much more probable than that Persian amateurs should have made them. The vigour and well-developed muscle so forcibly depicted in the figures, both human and animal, are clearly neither Persian nor Egyptian, but characteristically either Chaldean

or Assyrian. And it may be noted that about A.D. 1901 the French archæologist De Morgan, in company with the monk Scheil, found at Susa a diorite block upon which were inscribed 282 paragraphs of the laws of King Hammurabi of Babylon, B.C. 2250. (*Babel and Bible*, p. 185, Williams & Norgate.)

History tells also of a Median example, namely, the city of Ecbatana, of which Halsey Ricardo has said :—" In Mesopotamia the Medes built the town of Ecbatana. Up the sides of a steep hill rose the seven circular walls, one inside the other, enfolding the treasury and the king's palace. The outer wall was of immense diameter, and the terraces enclosed by each ring carried collections of country houses with small farm and gardens attached. . . . . The city was consecrated to the great powers of the firmament, and the devotion of its founder was registered in the form and colour of its walls. The battlements to the outer wall were white; to the next, black; the third, scarlet; the fourth, blue; the fifth, orange; the two last walls had their battlements silvered and gilt. Returning from an expedition or from the chase, there stood before the eyes of the beholder the city of his home, voicing in its chords of colour the seven great orbs that guarded his family and hearth—the sun, the moon, and the five planets—who rose and set in ceaseless vigilance. . . . . This profusion of colour and metal-work strikes us as extravagant . . . . but Herodotus dealt with facts well known to many of his readers who had seen Nineveh and Babylon and the pictured splendour of Egypt; and this is how he describes Ecbatana. Amidst this wealth of artificial colour grew up the art of Persia." (*Arch. Rev.*, pp. 118, 119, April 1902.)

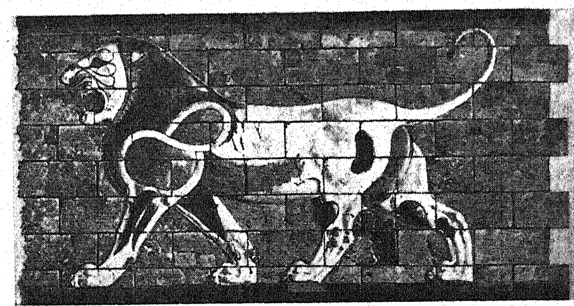

FIG. 34.—Portion of frieze of lions, from replica in Victoria and Albert Museum. (*By permission of the Board of Education.*)

Less than a century perhaps after the height of luxury at Susa, the ebb-tide of Achæmenian power and splendour set in. In B.C. 335–334 Alexander the Great crossed the Hellespont with a large army, and by B.C. 330 Susa and Persepolis were under the dominion of the Macedonian, and the ancient history of Persia was a closed chapter. Thenceforward for nearly five hundred years the Persian remnant shrank within their own circumscribed boundaries and learned what it was to "wear the yoke." Meanwhile, about B.C. 250, arose the Parthian Empire, which eventually extended its dominion over many territories between the Indus and the Tigris. (See *Persia*, by Vaux,

p. 121, S.P.C.K.) They, too, appear to have left no records, and their history has to be learned from what the Romans and the Armenians wrote about them. In course of time Parthia and Rome came in touch, and for years these Titan forces wrestled for supremacy. When at length the "mistress of the world" had humbled the proud and powerful Parthian "king of kings," then, forsooth, the Roman soldiery contracted disease in Babylonia, which scourged their empire through to the very shores of the Atlantic. (*Persia*, by Vaux, p. 148, S.P.C.K.)

Another long break in the chain of evidence relating to the continuity of the ceramic art in Persia demands explanation, namely, the period from A.D. 220 to A.D. 636. This is known as the Sassanian period. Parthia having been overpowered and devastated by the Romans, and the Romans debilitated by pestilence, the Persian remnant under Ardashur I. and Shahpur I. re-established an independent kingdom of their own, and once more the Persians (Sassanians) became powerful; even Egypt was entered again by them, and the inhabitants of Constantinople knew what it was to see a Persian camp at their door. The western capital of this empire was Ctesiphon, but they left few records apparently, for Vaux writes :—"We have but few materials for the early part of their history. Native and contemporary chronicles there are none." (*Persia*, p. 152, S.P.C.K.) Of ruins, those of the city of Shahpúr, about fifteen miles north of Kazerūn, are considered the most celebrated of Sassanian age. Authorities refer to a high state of civilization at this time, but no examples of ceramic decoration appear to be mentioned. This is not to be wondered at, for after Heraclius (about A.D. 628) had shattered the strength of the Sassanians, the Mohammadans found them an easy prey; and when Ctesiphon was captured, it is said that one-fifth of the entire booty, together with *all the works of art, was sent to Medina.* "The Arabian writers afterwards described in glowing colours the palaces and gardens, the beautiful streets, the luxury of the houses, and especially the royal palace, with its portico of twelve marble pillars, each 150 feet in height; its hall with vaulted roof, brilliant with stars of gold . . . . a carpet of white brocade, 450 feet long, with a border of precious stones." (*Extinct Civilizations of the East*, p. 219, Newnes.)

Possibly to this period may be ascribed certain fragments of early glazed wares from Persia, of uncertain date, which are rudely decorated with figures of men and animals, plants and leafage, painted on a sandy body beneath a silico-alkaline glaze; these things and the plunder of Sassanian cities may possibly account for the presence of leadless glazed tiles on the tomb of Mohammad at Medina, built A.D. 707.

Thus for many centuries little is to be learned of Persian decorative ceramics. Meanwhile, "old times were changed, old manners gone"; Chaldean models give place to Saracenic, Indian, and Chinese; palaces and temples

are displaced by mosques. Suddenly, about the twelfth century A.D., from somewhere spring up artistic tastes and art manufactures, such as have earned renown for the Persians in every civilized land, and spread its far-reaching influence through Asia, Africa, and Europe.

If it were necessary to trace continuity in this art in Persia from ancient times, the associations of the Chaldean-speaking portions of Persian peoples, together with the facts already referred to, are at our service. While the savage Parthian and the empire-fevered Roman were grappling in deadly grip, the colour-loving Chaldean may have quietly cherished and handed down, from generation to generation, the memories and crafts of Babylon, Ecbatana, and Susa.

Yet, again, *de novo* invention is possible to the sagacious Iranian, perhaps; and if there were not other explanations, this might pass for one of the possibilities of the problem. It is, however, equally important to recall that, at the commencement of the twelfth century, the principal Mohammadan invasion of India took place, and vast booty was deported, together with many captives, from Northern India, westward, by the victorious Mohammadans.

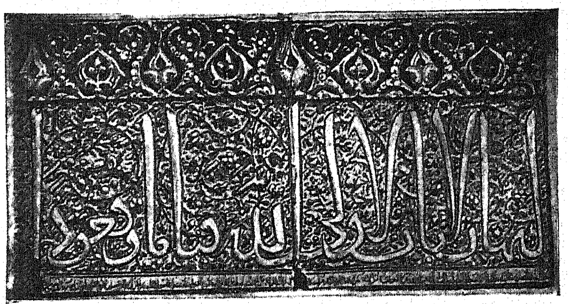

FIG. 35.—Persian inscribed tile, thirteenth century. (*By permission of the proprietors of "The Connoisseur."*)

Further, Sir John Malcolm, in his *History of Persia*, vol. i. p. 422, states that a hundred families of Chinese artisans and engineers came to Persia with Hulaku Khan about A.D. 1256. Among these may have been ceramists. (*Persian Arts*, p. 11, Chapman & Hall.) Afterwards, in A.D. 1402, occurred the great conquests of the Moguls under Tamerlane, of whom Sir George Birdwood said:—"In all the imperial Mogul cities of India where it [the art of glazed pottery] is practised, especially in Lahore and Delhi, the tradition is that it was introduced from China through Persia . . . . through the influence of Tamerlane's Chinese wife." (*Jour. Soc. Arts*, 28.2.79, p. 310.)

Add to this the fact that, until the discovery of the passage by the Cape of Good Hope (A.D. 1497), Persia was near to or upon the great highway of whatever commerce there was, from all time, between China and Europe. Thus we need make little call upon our imagination to find reasons for suspecting Chinese influence. (See *Persian Art*, p. 6.)

Hence, while ware of simple turquoise-blue glaze or of polychrome enamels may with justice be assumed to have had a Chaldean or Egyptian prototype,

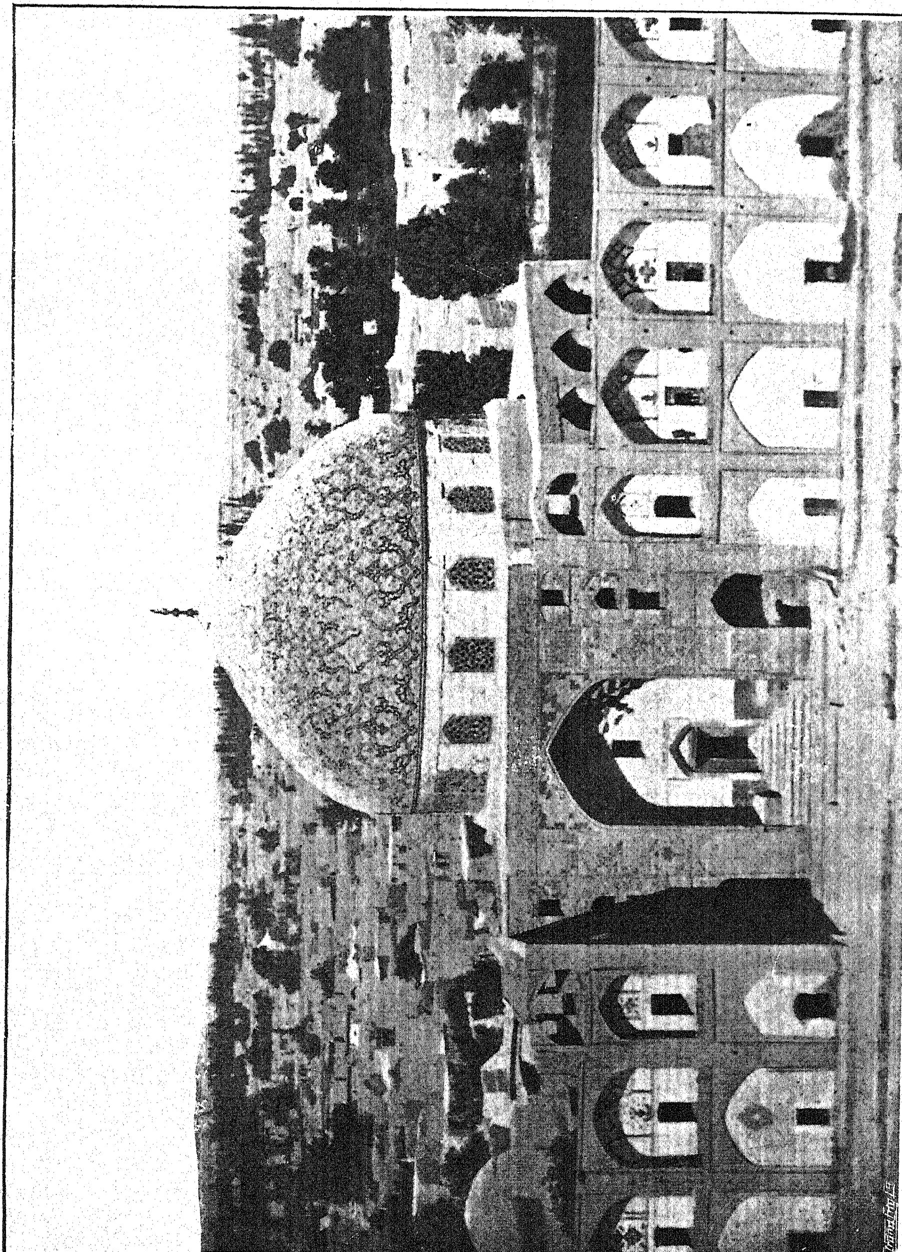

Fig. 36.—Mosque of Sheikh Lulf Allah at Ispahan. (*From a photograph in the Art Library, South Kensington. By permission of the Board of Education and of the Editor o the "Architectural Review."* See *Arch. Review*, April 1902, p. 126.)

on the other hand, conventional painting of flowers, etc., in blue on a white ground has such close resemblance to early Chinese methods, and appeared in Persia at a period so exactly synchronizing with the events above related, that it seems most reasonable to assign to it a Chinese or Mongolian origination.

Nevertheless, Sir R. M. Smith writes:—"Persian art is, if possible, still less indebted to the Moghul than to the Arab invaders of the country. The successive hordes of Chenghiz Khan, Halaku, and Tamerlane, as well as the fanatic rule of the lieutenants of Omar, served only to destroy much that had previously existed. Some of the descendants of these conquerors, it is true, became, like the Arab kalifs, patrons and promoters of art and science. The productions of their time, however, are none the less the work of the native Aryans." (*Persian Arts*, p. 5.)

The mosques are mostly closed to Europeans, but one of the highly decorated Sheah-Mohammedan shrines of Persia is that of Meshed 'Alí, and to this Mr. W. K. Loftus once had the good luck to obtain access. In his *Chaldæa and Susiana* he has given a graphic description of his visit. After detailing the incidents and perils of the attempt, he speaks of its ornamentation thus:—"It is all but impossible to convey to the mind of another the impression produced on the senses by the first inspection of a Persian mosque. The extreme richness and brilliancy of the polychromatic decoration, and the exquisite harmony of the whole, cannot fail to leave a lasting impression. . . . . Like the generality of mosques, that of Meshed 'Alí is arranged in the form of a rectangle. The mausoleum stands nearly in the centre of a large court, the walls of which, as well as those of the principal building, are adorned from top to base with square encaustic tiles. The design on these is a succession of scrolls, leaves, and doves wrought into the most intricate patterns. The colours, though bright, are so admirably and harmoniously blended and softened down by lines of white, that the surface appears like a rich mosaic set in silver. Each wall is divided into two tiers of blind arches, ornamented throughout in a similar manner, above each of which are texts from the Koran written in letters of gold. Two highly decorated gateways, deeply set in lofty flat panels, give admission to the great court of the mosque, and serve to relieve the otherwise monotonous aspect of the enclosure. The summit of the mausoleum walls are likewise surrounded by passages from the Koran. At three corners are minarets, two of which in front are covered throughout with gilt tiles, said to have cost two tomāns (£1 sterling) each. These, together with a magnificent dome of the same costly material, give to the *tout ensemble* a gorgeous appearance. Seen in the distance, with the sun shining upon it, the dome of Meshed 'Alí might be mistaken for a mound of gold. . . . . The tomb of the great saint was not for infidels to approach and defile, but the Ghyáwr were perfectly content with the sight they were

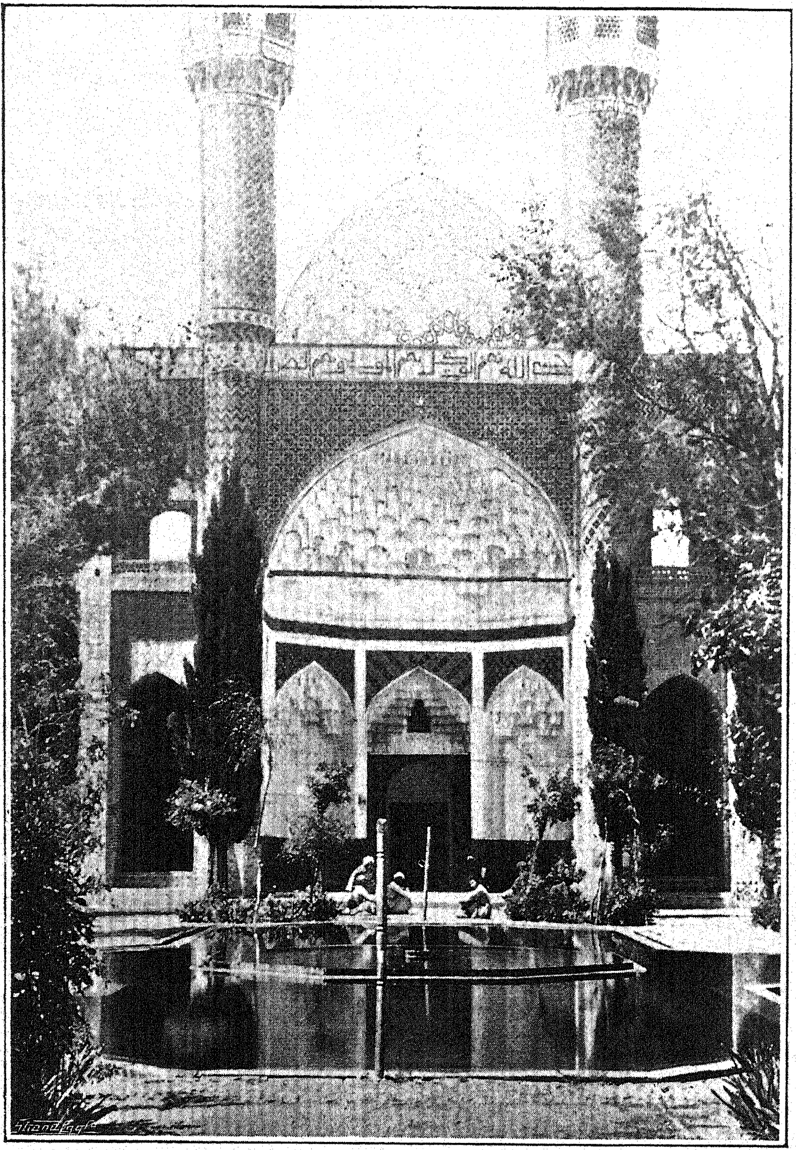

FIG. 37.—The Mahun Shrine near Kerman. (*By permission of the Royal Geographical Society and the proprietors of the "Architectural Review."* See *Arch. Review*, April 1902, p. 122.)

permitted to behold in the court of the mosque. . . . We did not tarry long, as it was evident, from the demeanour of those around us, that we were not welcome. . . . . We slowly retired, casting a last lingering glance on this noble and fascinating specimen of Persian art." (*Chaldæa and Susiana*, p. 53, Nesbit.)

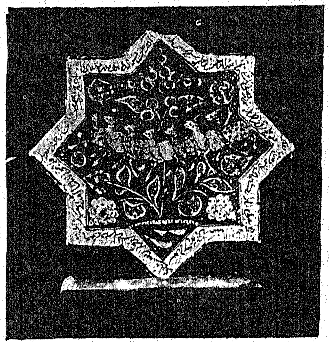

FIG. 38.—Persian star tile. (*By permission of the proprietors of "The Connoisseur."*)

Sir George Birdwood also has given a glowing description of these Eastern ceramics. Long ago he wrote:—"The sight of wonder is, when travelling over the plains of Persia or India, suddenly to come upon an encaustic-tiled mosque. It is coloured all over in yellow, green, blue, and other hues; and as a distant view is caught of it at sunrise, its stately domes and glittering minarets seem made of purest gold . . . . a fairy-like apparition of inexpressible grace and most enchanting splendour." (*Industrial Arts of India*, p. 140.)

With regard to the later Mohammedan-Persian decorative ceramics, Sir R. Murdoch Smith states that, "In the sixteenth and seventeenth centuries

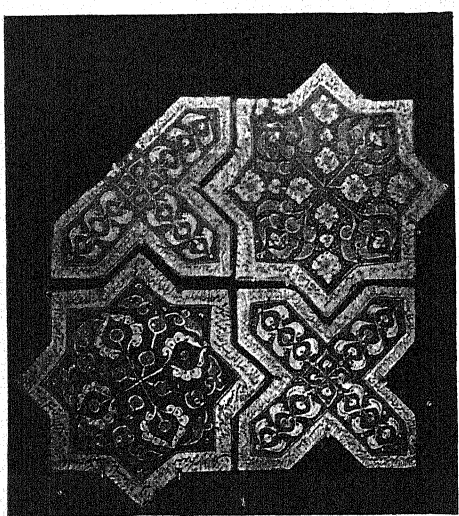

FIG. 39.—Persian star and cruciform tile, thirteenth century. (*By permission of the proprietors of "The Connoisseur."* See *Connoisseur*, November 1903, p. 164.)

FIG. 40.—Persian tile, thirteenth century. No. 1841—176, South Kensington Museum. (*By permission of the Board of Education.*)

unlustred and even surfaced tiles of bright colours and very varied floral designs were extensively used in decorating the walls of public buildings. . . .

Sometimes the design covers several bricks, but more usually the pattern is formed by a mosaic of small tiles, each of only one colour. Gateways of cities, of caravanseras, and of large buildings are usually embellished in this manner." (*Persian Arts*, p. 36, Chapman & Hall.)

M. Texier ascribes the tiles, both of the mosque and the palace at Ispahan (the former capital of Persia), to the seventeenth century. The palace is said to be decorated with large tableaux representing Persian history, composed of tiles or bricks of several colours. (*Traité des Arts Céramiques*, vol. ii. p. 87.)

Sir C. Purdon Clarke, C.I.E., Director of the Victoria and Albert Museum, holds the opinion that about the sixteenth century a colony of Chinese potters was introduced into Persia, and that their descendants still live near Ispahan, and are called Bacha-Chinese, or sons of the Chinese. This circumstance may account for the Chinese *motif* in Persian work of sixteenth and seventeenth centuries. The old coloured enamels, applied either *cloisonné* or mosaic fashion, are thus augmented by painted designs in blue on white, so like Chinese products.

So, also, Persian turquoise-glazed wares have their counterpart in India, in work of the Pathan period (twelfth and thirteenth centuries A.D.), and Persian floral-painted patterns their counterpart in Indian ceramic products of the Moghul period (sixteenth and seventeenth centuries A.D.)

It would be interesting to know what districts of Persia were the chief centres of ceramic manufacture. Of course, these would inevitably shift with the shifting of the metropolis from age to age, and naturally would gather round the centres of habitation of the period as far as practicable.

Fergusson tells of the use of tiles at Tiflis, Ispahan, and Teheran, but, as far as we know, gives no clue to the makers' names or abode. From Sir R. Murdoch Smith, however, we learn that "The chief seat of earthenware manufacture was Kashan and the neighbourhood, including Nain, where good clay is still found. Cobalt, the colour chiefly used, is also found at Kashan and Koom. The common name for Persian earthenware is still 'Kashi Kari' or Kashan work." (*Persian Arts*, p. 25, Chapman & Hall.)

Again, according to Sir George Birdwood, the Semitic word Kas, meaning glass, is in use both in Arabic and Hebrew, and the art of glazing earthenware is known in Persia by the name Kasi. (*Jour. Soc. Arts*, 28.2.1879, p. 311.)

Rhé or Rhages, also, in its day (*i.e.*, anterior to A.D. 1256) was probably a seat of ceramic industry, pieces spoilt in the baking having been found on the site, and even remains of potters' kilns. (*Persian Arts*, pp. 21–23, Chapman & Hall.) Many fragments of lustred ware have also been found there, as well as in the district of Kashan; and according to Sir R. M. Smith, the paste or body of lustred tiles often resembles that of the old bricks with which the site of Rhé or Rhages is covered. It is therefore quite likely that this great city was, at some period of its existence, one of the chief centres of the trade.

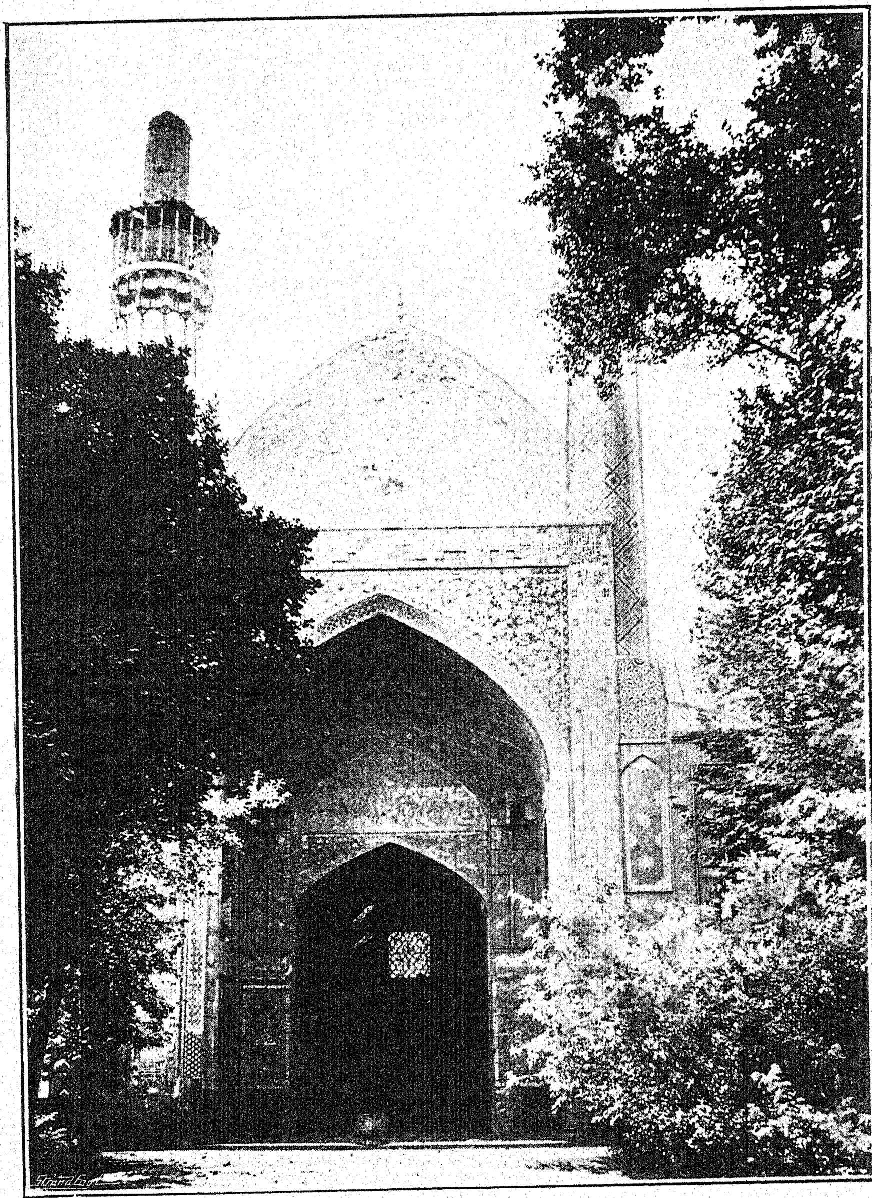

FIG. 41.—Hadrasi i Ispahan. (*By permission of the Royal Geographical Society and the proprietors of the "Architectural Review."* See *Arch. Rev.*, April 1902, p. 122.)

Beautiful lustred fragments and tiles are said to have been recently found by Major Sykes among the ruins of Kerman. (See *Connoisseur*, September 1903, p. 22.)

Experts and connoisseurs never tire of praising Persian tiles. Mr. Sparkes, of the Royal College of Art, said:—"Persian tiles looked as if a piece of glass had actually been melted down on the surface, so enormously thick was the glaze. That thickness was one of the greatest factors to the pleasure one had in looking at a piece of Persian ware; it was the depth through which the rays of light passed to the background, that was missing in the modern ware completely." (*Jour. Soc. Arts*, 17th February 1893.)

FIG. 42.—Persian tile, seventeenth century. (*By permission of the proprietors of "The Connoisseur."*)

Mr. H. Longden has said:—"To his mind, Persian tiles were the most beautiful that were ever made. If anyone wished to get the finest colouring in tiles they must look to Persia." (*Jour. Soc. Arts*, pp. 713, 3.6.1892.)

Mr. W. Burton, F.C.S., in a lecture at Hanley (February 1891), remarked:—"At a very early time, certainly as early as the Christian era, the Persians had learned the secret of manufacturing a true glaze, and their glaze was of a very simple composition, consisting of a mixture of clean white sand and either soda or wood-ashes or potass. Glazes of this nature were very brilliant in appearance, very good for developing colours, and in the case of the Persians, they adhered perfectly well to the ware. One of the striking peculiarities of all alkaline glazes was their extraordinary brilliance. . . . . From about the eleventh to the seventeenth century the Persians were perhaps the best decorative artists the world had ever seen." (*Sentinel*, 23rd February 1891.)

One of the most distinctive characteristics of Persian ceramics was their lustre; and unless in some way learned from China or India, this seems to have been their own *de novo* invention. W. De Morgan is of opinion that neither Assyrians nor Egyptians practised this method of enhancing the artistic effect of their wares. Even in Persia itself, lustring had a short existence; the earliest specimens known being those from the ruins of Rhages, whilst the art has been lost in Persia since the reign of Shah Abbas, A.D. 1665.

The superb example of Persian coloured tilework which we are permitted

PERSIAN ENAMELLED TILE—WORK.

Typical example selected by C. Stanley Clarke, Esq. Indian Section. Victoria and Albert Museum.

Pl. IX.

ANDRE & SLEIGH, LTD., BUSHEY, HERTS.

Panel of Enamelled Earthenware Tiles. Persian. About 1600 A.D.

Formerly part of a dado in the Palace of Chehel Sitún. Ispahan.

Acquired by the Victoria and Albert Museum in 1891.

(Illustrated by permission of the Director, V. & A. M.).

to illustrate (Plate IX.) by the Director of the Victoria and Albert Museum, London, and which was kindly selected for this publication as a typical specimen of Persian art, of about A.D. 1600, by C. S. Clarke, Esq., of the Indian Section, is described as a panel of earthenware consisting of thirty-six tiles and a border which are enamelled in colours. A princess, clad in richly decorated garments and wearing a diadem, is reclining on cushions beneath the shade of trees in a garden. Her attendants, two on one side and three on the other, are similarly dressed, and offer her refreshments in bowls and long-necked bottles. On either side of the lady are two cypress trees. The border, which runs along the top and down both sides, is composed of a repeating design of leafy scrolls and Chinese clouds. There is a depression in the centre for a niche. This panel formed part of a dado in the pavilion of Chehel Sitún or the forty columns, Ispahan, built during the reign of Shah Abbas I. (1587–1628). Size, height 3 feet 7 inches, length 7 feet 3 inches. . . . . 139—1891. S.K.M.

C. Stanley Clarke, Esq., refers to this magnificent original piece of Persian tilework from Ispahan as an exceedingly fine and well-known piece, of gorgeous colouring, and typically Persian.

FIG. 43. — Persian tile, seventeenth century. Victoria and Albert Museum. (*By permission of the Board of Education.*)

The British Museum also contains interesting examples of Persian wall-tiles, particularly of the thirteenth and fourteenth centuries, but those already referred to amply represent this section of our subject.

Summing up the bearing of this delight in colour among the Persians, Sir R. M. Smith remarks:—" The style of Persian art, innate as it is to the country is in many respects illustrative of the national character, so truly depicted in the inimitable pages of Morier's *Hajji Baba*, a work which may be taken as a moral photograph of the nation. The lively and poetical imagination of the Persians . . . . finds vent in the varied and symmetrical intricacy of the ornamentation with which they delight to decorate the surface of even the poorest materials, while their want of many of the sterner virtues leads them to neglect . . . . everything which does not at once appeal to the eye of the beholder. Thus the beautiful tiles with which their public and private

buildings were adorned only too often concealed the meanness in other respects of the structures themselves. . . . . The beauties of their art, as of their character, lie on the surface, while the defects of both are carefully concealed by a pleasing lacquer of polished refinement." (*Persian Arts*, p. 5, Chapman & Hall.)

Syrian.—Glazed or enamelled tilework very like Persian was used in Syria and parts of Asia Minor during mediæval times, but no mention of ancient examples of pre-Mohammedan age have come under my notice: yet, as Syria lay between countries eminent for their ceramics—countries, indeed, that apparently were somewhat indebted to each other in these matters, Egypt and Assyria—ancient examples might reasonably have been expected. In connection with Syria's share in the use of decorative ceramics, Europeans naturally turn to Bible history. Therein we find one point of considerable significance, namely, the absence of tile-decoration of any description whatever in the successive Jewish temples at Jerusalem. When King Solomon built his world-renowned temple, B.C. 1012, he makes no reference to glazed tiles. The temple was built of hewn stones, great and costly, and of cedar of Lebanon; "and the floor of the house he overlaid with gold within and without" (1 Kings v. and vi.). Thirty-three years later this superb temple was plundered by Shishak, King of Egypt, whose army is believed to have carried away the plates of gold. By B.C. 889 it had fallen into great decay, and was then repaired; but at length was utterly destroyed by Nebuchadnezzar. Another temple, built about 516 B.C., was of similar materials, and still no mention of glazed tiles; yet Jews, Persians, and Phœnicians were all concerned in it.

When, in turn, Zerubbabel's temple had become unfit, and Herod, to conciliate the Jews, began to rebuild—B.C. 16—we still hear nothing of decorative tiles: yet, it is said, 18,000 men were employed in the work, and the stones were mostly white marble and unspeakably beautiful. Instead of doors the gate was closed with veils, flowered with gold. Double rows of Corinthian columns formed the outer courts on the west, north, and east. And a "Royal Porch" formed a principal entrance on the south. This temple was the one destroyed by the Romans, A.D. 70.

If this omission or absence of ornamental faience arose from religious motives, one might have expected some comment to that effect; and, at least, in the case of the city of Tadmor, built by Solomon, about B.C. 1000, such motives would have had less force by reason of its cosmopolitan situation and object. The Greeks afterwards named this same city Palmyra, and in the course of its existence and prosperity Jews, Greeks, and Romans had much to do with it; Mesopotamians, Persians, and Parthians also can scarcely fail to have been frequently there. Rev. J. L. Porter visited its ruins about A.D. 1863, and describes them as almost unsurpassed in the world for beauty

and extent; yet, notwithstanding exceedingly rich and chaste interior decorations, we hear nothing of tiles.

If the art of the ceramist decorator had any active existence during this long period, these considerations appear to place its locale far outside the sphere of Jewish, Greek, and Roman influence, and render its ultimate revival all the more remarkable.

Fortnum, in his catalogue of Damascus tiles in the Ashmolean Museum (Oxford), assigns none to an earlier date than the fourteenth century A.D., and nearly all are catalogued as fifteenth and sixteenth century; and the specimen from Baalbec, mentioned by Brongniart (vol. ii. p. 91, *Traité des Arts Céramiques*), is assigned to the ninth century A.D.

FIG. 44.—Damascus tile. (*By permission of the proprietors of "The Connoisseur."*)

Nevertheless, Damascus, the capital of Syria, is a very ancient city. Rev. J. L. Porter wrote:—"By whomsoever founded, one thing is certain regarding Damascus. When Abraham crossed the desert from Haran 3800 years ago, the city was already standing on the banks of the Abana; and from that day till this it has held a first place among the capitals of Western Asia. It has seen many changes. It has passed through many hands. It has been ruled by many masters. Syrians, Persians, Greeks, Romans, Arabs, and Turks have in turn governed or oppressed it; but it has lived and flourished under them all. . . . . Twelve times it had been pillaged and burned; yet it has always arisen with new beauty from its ashes." (*Syria's Holy Places.*)

In the *Temple Magazine* of April 1903, from which we are kindly allowed to make excerpts and reprint illustration by the courtesy of Paget Baxter, Esq., and the proprietors of the *Cosmopolitan Magazine*, Dulany Hunter very graphically describes Damascus of to-day, with its cool covered streets, its luxurious baths, with domes heaped one upon another like bubbles, its

blue-tiled courts in which are wide divans, its great reception-rooms, its floors of variegated marbles, its walls incrusted with alabaster, porphyry, and lapis

FIG. 45.—Damascus. A picturesque locality.

lazuli, its gardens with even greater charm, stretching for miles around the city, "beside silvery seas of shimmering olives amid a wilderness of groves of fruit."

"Thus lightly," he tells us, "does Damascus wear her years. She has had a longer continuous existence than any city that is standing in the world to-day. . . . . After the fall of Nineveh, she passed under the sway of Babylon, like almost all the cities of the East, and afterwards she was forced to bear the heavy yoke of Persia—it was within her walls that Darius left his family and treasure when he went to meet Philip of Macedon on the fatal field of Issus. . . . . Over this garden-spot of the desert there has been eternal conflict. Bloodshed has been its portion, and century after century has witnessed battle without and massacre within its walls. . . . . In it Pompey spent the proudest year of his life (64 B.C.)."

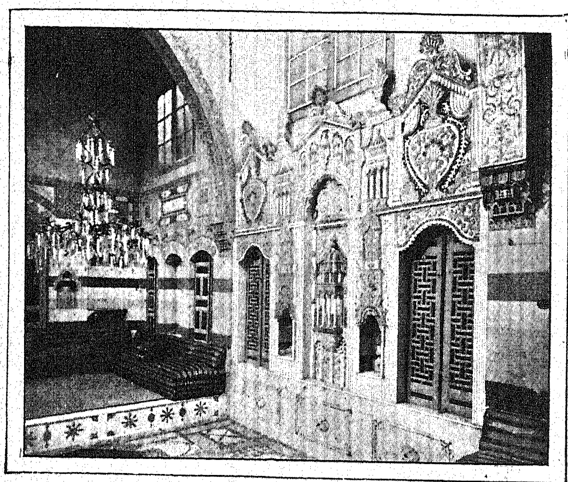

FIG. 46.—An interior.

Long afterwards came the Saracens, and upon the ashes of her former splendour built a kind of fairy capital. But now, again, "Her palaces have fallen, most of her mosques have crumbled away . . . . in turn, all save one of the fair edifices of the Saracens have perished, but around this existing monument, this temple known as the Mosque of the Omeyyades, there throbs to-day the same life that beat so gloriously in the time of the caliphs, and there are few places more interesting in the broad domains of el Islam than the splendid precincts of this ruined fabric of Arabian architecture" (fig. 49).

The causes that influenced ceramic art in Persia and India very greatly influenced that of Syria and other portions of the Turkish Empire, and by

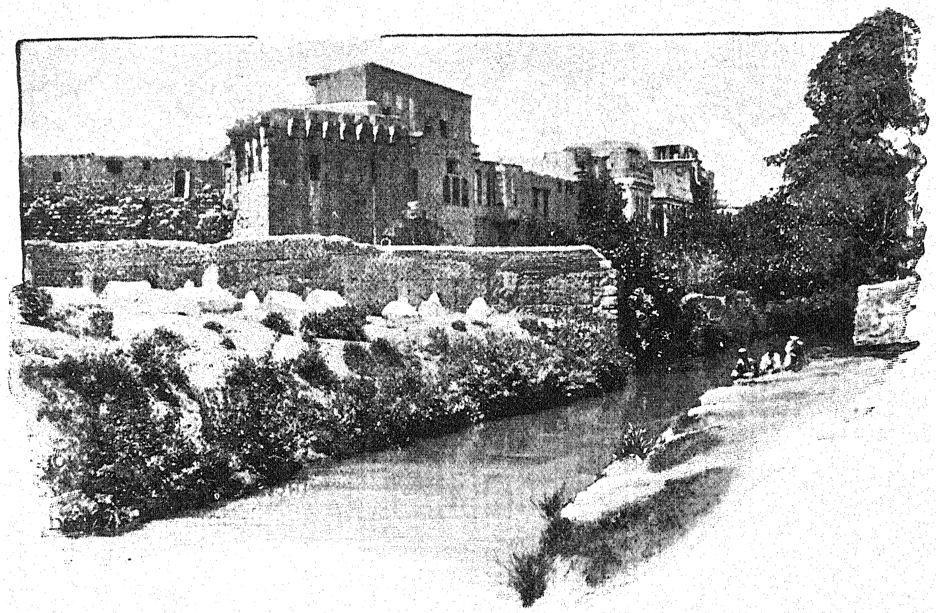

FIG. 47.—The house of Ananias.

the seventeenth century the similarity of product is remarkable. By the consent of Sir C. Purdon Clarke, C.I.E., Director of the Victoria and Albert Museum, and by the kind assistance of C. Stanley Clarke, Esq., of the Indian Section (V. and A. M.), who has selected typical examples, Syrian and Turkish tilework of the sixteenth and seventeenth centuries have been illustrated in colour on Plate X. by the three-colour block process.

Fig. 50 illustrates a Damascus tile, with an unmistakably Chinese *motif* in the design, yet both body and glaze have Egyptian characteristics, except that the body effervesces slightly to acids. No engobe or slip-wash can be detected; the glaze appears to have been applied directly upon the body.

The glaze is transparent, colourless, and of somewhat vesicular nature, and slightly inclined to eggshell-like surface, yet quite glossy enough for mural decoration.

The colours are dark blue, turquoise, grass green, and purple brown, and these are painted boldly on a white ground in conventional floral style, either under glaze or on glaze, and then burnt in with the glaze at the same firing, and the colours flow into the glaze.

It has a particularly effective design, well proportioned for decorative purposes. Similar conventional hyacinths and asters or crysanthemums appear on a Tazza of Damascus ware, figured by Fortnum on plate iii., *Catalogue of Maiolica in Ashmolean Museum*, which is attributed to the sixteenth century.

FIG. 48.—Tekiyeh. Dervish mosque.

Some fifteen tiles, classed by Fortnum as Damascus tiles, in the Ashmolean Museum, Oxford, are described in the catalogue as having a white ground, ornamented with conventional floral sprays, painted in dark blue, etc., under or into a colourless transparent glaze. This style therefore seems typical. The tiles referred to measure 6½ inches by 6½ inches, 8 inches by 7½ inches, 10 inches by 8½ inches, 10 inches by 4½ inches, 9 inches by 9 inches, and similar sizes.

Other typically Damascus tiles are elaborately ornamented in green, turquoise blue, and dark blue, such as No. 949—73, S.K.M. (fig. 51).

The absence of red colour on Damascus tiles, for which a peculiar purple—very like Egyptian—serves, is characteristic, and distinguishes them from Rhodian tiles.

Upon close examination of either Persian, Syrian, Rhodian, or Turkish

SYRIAN AND TURKISH TILES.

Typical examples selected by C. Stanley Clarke, Esq. Indian Section. Victoria and Albert Museum.

PL. X.

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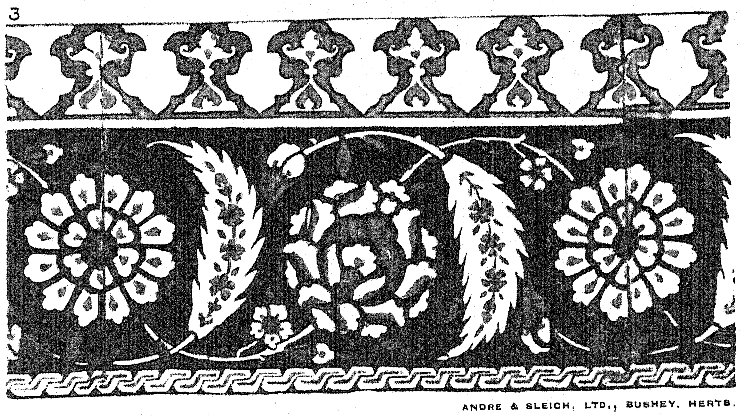


ANDRE & SLEICH, LTD., BUSHEY, HERTS.

1. Turkish. 16th Century. V. & A. M.
2. Syrian (Damascus). 17th Century. V. & A. M.
3. Turkish: about 1500 A.D. V. & A. M.

(Illustrated by permission of the Directors V & A. M.).

tiles, it may often be noticed that where cupreous grass-green colour has been applied, the glaze surface is depressed, as though the copper salt had induced vitrifaction of the siliceous body, and so caused shrinkage of the particular parts to which the colour had been applied. The red colour on Rhodian or Turkish tiles, on the contrary, almost invariably exhibits a distinctly raised surface wherever applied.

Fortnum expresses the opinion that potteries were in operation at all the principal sites of manufacturing industry throughout Syria and Asia Minor, for the making of richly painted tiles in conventional and floral designs such as were used on the mosques and tombs of Constantinople, Broussa, and Jerusalem. The pottery, he tells us, was composed of a sandy and aluminous paste, sometimes of fine grain, sometimes coarse grained, and of a siliceous nature; while on the finer pieces a thin wash of white clay or stanniferous enamel may be found beneath the rich vitreous glaze, the tiles being of the same general character as the pottery. The colours used are mostly blues and greens, among which are an intense lapis and a brilliant turquoise; some red, a dull purple, and some yellow. (*Catalogue to Maiolica, Ashmolean Museum, Oxford*, pp. 10, 11.)

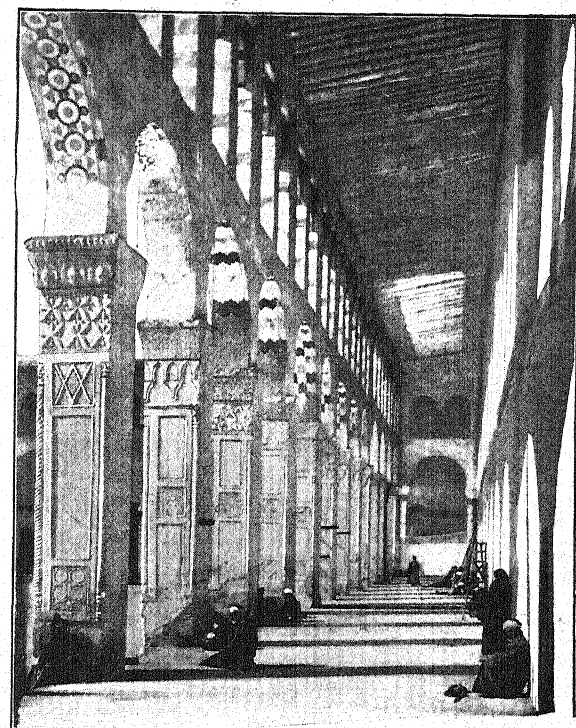


FIG. 49.—Colonnade of the Grand Mosque.

Of the specimen from Baalbec, or Balbeck, Brongniart remarks that it is like Arab work, but produced in a little different manner. It has a hard white body, yet sandy and porous; a pale green-blue glaze, with black ornamentation; the fragment, although very small, sufficed to enable them to learn that the glaze did not contain lead. Its date is supposed to be about the ninth century. (*Traité des Arts Céramiques*, vol. ii. p. 91.)

At Baalbec, the ancient, the classical, and the mediæval appear to have

met and parted; the erstwhile costly sculpture and architecture of magnificent temples are now but mazes of ruins. The great temple of Baal, the temple of Venus, the Roman temple of Jupiter, the Saracen Citadel, all have fared alike; and now but an insignificant village suffices for its inhabitants. It is situated between Beyrout and Damascus; but apparently furnishes no prominent example of faience decoration.

FIG. 50.—Damascus tile. (W.N.F. Coll.)

Reverting again to Jerusalem: the shrine of Omar, or the "Dome of the Rock," is possibly the most impressive example of the use of decorative tilework in Syria. This, fortunately, has been often and ably described. For our purposes the description of an eyewitness — Mr. T. R Spence (London) —which appeared in the *Architectural Review* of December 1899, will provide all that is needed. Referring to the exterior, he says:—"Each side of the vertical portion supporting the dome is covered with exquisitely coloured Kâshâni tiles carried over both the flat surfaces and what may be called the frame faces of the windows, which are of stone and pierced with polygonal openings. The combination of the shadowed forms of these incisions, combined with the brilliant covering of the face of the framework, is a decorative triumph. Under the cornice of the dome runs a striking decorative tile frieze of quotations from the Koran."

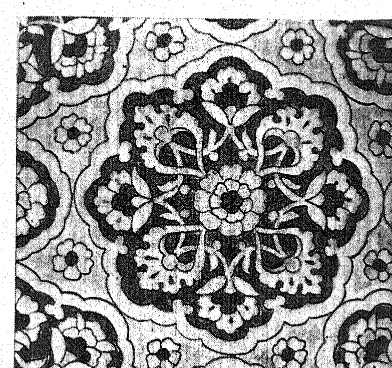


FIG. 51.—Damascus tile, sixteenth century. 949—73, S.K.M. (*By permission of the Board of Education.*)

"The interior," he writes, "in the dim reflected and diffused light, is a dream of luscious colour in mosaic, gold, iron, and marble." (*Arch. Rev.*, December 1899, p. 258.)

According to Murray's *Handbook to Syria and Palestine* (pp. 96, 97), the date of its erection is 688 A.D., the

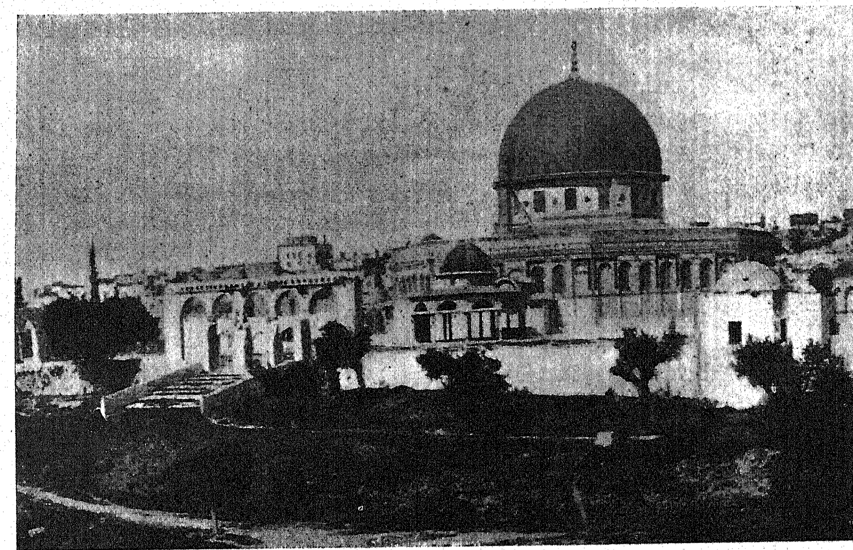


FIG. 52.—Mosque of Omar, Jerusalem. (See *Architectural Review*, December 1899, p. 257. *By permission of the Technicals Journals, Ltd.*)

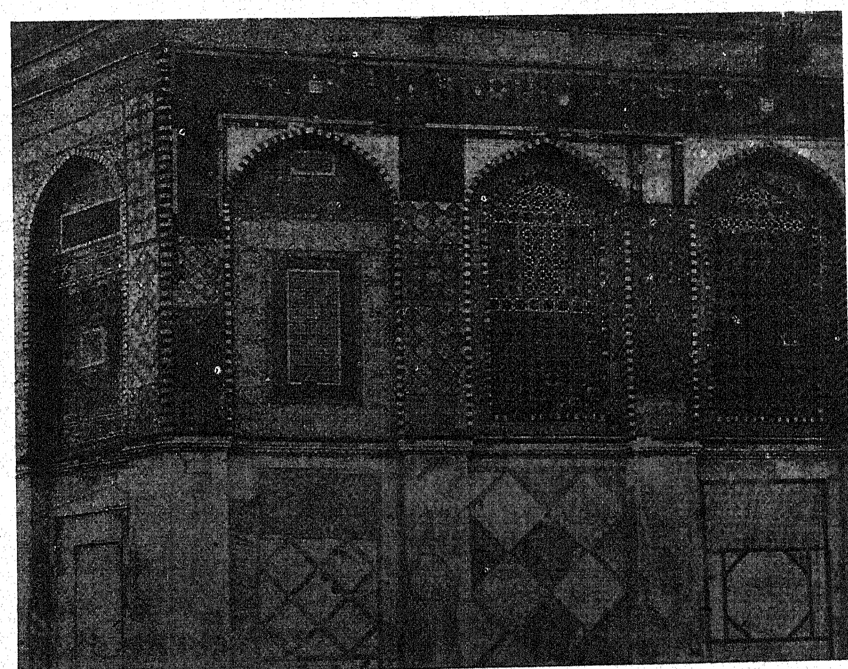


FIG. 53.—Exterior detail of the Mosque of Omar. (See *Architectural Review*, December 1899, p. 259. *By permission of the Technicals Journals, Ltd.*)

date of the windows 1528, and the date when the exterior was adorned with the Kâshâni tiles 1561 A.D.

Brongniart mentions a small fragment of a tile from the Mosque of Jerusalem as being in the Céramique Museum at Sèvres. He describes this fragment as having a turquoise-blue ground with dark blue ornamentation, the glaze being free from lead; the body is sandy and resembles stone; so much so that he suspects it to be a rock of some kind that has been enamelled.

Brongniart also gives the following as Salvetat's analysis of the body or stone of an enamelled brick from Jerusalem:—

Silica,	87·16
Alumina and iron,	5·50
Lime,	3·00
Magnesia,	0·28
Carbonic acid,	2·86
Potash and moisture,	1·20

Another building in Jerusalem to which Mr. Spence refers is the Armenian Monastery. In the church of this, he tells us, there is a very large area of beautiful Arabic tiles, quite as interesting as those on the Omar Shrine. "It is like a choice museum of the arts and crafts—rich in beautiful brass and silver lamps, knockers, inlays, tiles, and carvings in cedar and other woods. The chapel walls are lined with lovely Persian tiles to a height of 9 feet or 10 feet."

In conclusion he adds, rather sadly:—"It seems to me that a guardian angel should conduct you over Jerusalem . . . . shedding on you a happy forgetfulness of its poverty, its dirt, cruelty, and disease, its bigotry, its feuds and scrambles for holy sites, its carrion, its squalor, and the sun-baked desolation of its noontide. With him either in the rose of dawn or the gold, amber, and purple of early twilight, to wind through the grey-green trees and down the stony slopes . . . . then Jerusalem is divinely beautiful." (*Arch. Rev.*, December 1899.)

Rhodian.—According to some authorities, both Damascus tiles and those called Rhodian were made by Persian artists working respectively at Damascus and on the Isle of Rhodes, the Rhodian tiles usually being characterized by having portions of the decoration in strong red underglaze colour. All appear to have been manufactured by a process in some way derived from the Persian, viz., with a white siliceous engobe, upon which the decoration is placed, and the whole then glazed with a transparent silico-alkaline glaze. Or at times when the body was white enough for the purpose, the engobe may have been omitted, and the colour merely applied on the glaze before burning. Binns pronounces their underglaze red "the marvel of all who understand the difficulties of the case."

According to Fortnum, the chief site of production was probably Lindus, where, it is stated, remains of potteries have been found. He considers Rhodian wares colonial productions, so to speak, by Damascus or Anatolian potters and their descendants, who became established in the island of Rhodes; and he tells us the earlier are very superior to the later productions. Fortnum also shows that "red" colour appears on Anatolian wares, and that on Rhodian the rose, aster, and carnation frequently occur in the design.

Saracenic or Arab-Mohammedan.—Tytler asserts that the Saracens are mentioned in history for the first time when they defeated the Romans A.D. 189. Internal quarrels and external attacks thereafter occupied the Romans too fully to enable them to crush this rising power. By A.D. 547 Rome herself was overcome, and thirty years later Latin ceased to be used as a mother-tongue.

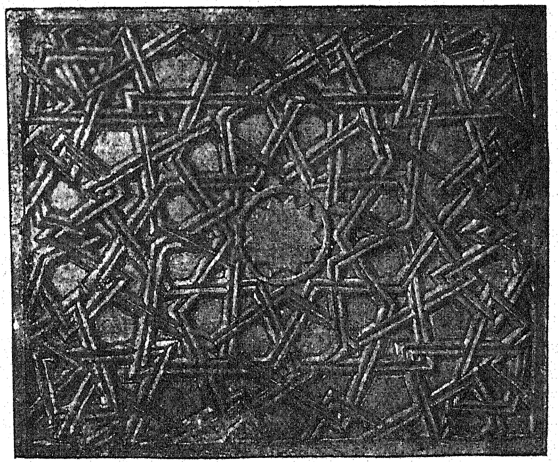


FIG. 54.—Saracenic tile. (*By permission of the proprietors of "The Connoisseur."*)

About this time (A.D. 569) Mohammed was born. In course of time he became caliph of the Saracens, and, joined by the brave Omar, in a few years overcame all opposition to his pretensions and authority in Arabia and parts of Syria. Mohammed died A.D. 632, at the age of sixty-three. He was succeeded by Abubeker, who took Jerusalem: in two years Abubeker died, and Omar was elected caliph. Under his leadership, Syria, Phœnicia, Mesopotamia, Chaldea, Persia, Egypt, Lydia, and Numidia were subjected to the Mohammedan supremacy; Spain being conquered by the Morocco section A.D. 713; and but for the stout defence of Rome itself by Pope Leo IV. in A.D. 848, Italy too must have been added to the great empire of the Saracen.

At a comparatively early period in their national existence, the Saracens used glazed tiles for decorative purposes, for the tomb of Mohammed at Medina, built A.D. 707, was lined with tiles. Whether these were manufactured by the Arabs, or by artisans from Susiana or from Egypt; or whether they were loot from Susa, or from Sakkarah, or Tell el Yehûdîyeh, may never be ascertained, but this circumstance seems to have set the example to all the faithful thereafter.

Brongniart tells us the glaze upon these tiles is *silico-alcaline*, and that in

the Sèvres Museum there is a most interesting piece of decorative ware from the tomb, namely, a mural plaque, about 9½ inches long, ½-inch wide, and ¼-inch thick. The body is whitish and siliceous, but hard, and covered with a good glaze, well made. Across the centre is a streak of black, dividing the plaque lengthwise into two divisions, one of which is green, the other blue, neither of which contains either lead or tin. It is a silico-alcaline glaze analogous to that of Egyptian. The body of this plaque or tile, writes Brongniart, compares in character rather with the so-called porcelain of Egypt. The analysis by M. Salvetat of the body of a plaque from the tomb of Mahomet at Medina is given as follows:—Silica, 89·95; alumina and iron, 3·87; lime, 2·00; magnesia, 0·51; potash and moisture, 3·0. (*Traité des Arts Céramiques*, vol. ii. p. 92.)

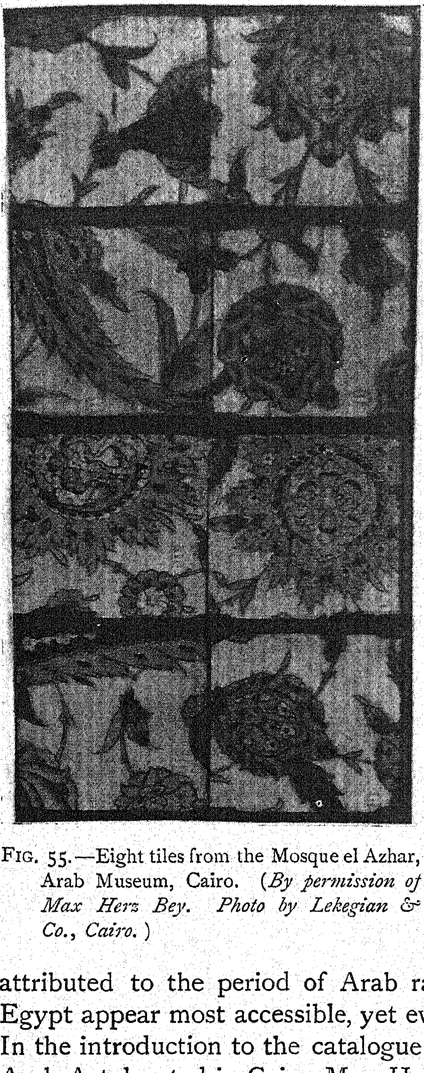


FIG. 55.—Eight tiles from the Mosque el Azhar, Arab Museum, Cairo. (*By permission of Max Herz Bey. Photo by Lekegian & Co., Cairo.*)

Sir George Birdwood says:—"The Saracens from the first used glazed tiles for covering walls and roofs and pavements, and of course with a view to decorative effect. The use of these tiles had come down to them in an unbroken tradition from the times of the Birs Nimrûd, of the Temple of Seven Spheres at Borsippa, of the temple of Sakkara in Egypt. . . . . Glazed tiles had, however, fallen into comparative disuse before the rise of the Saracens, and it was, undoubtedly, the conquests of Chingiz Khan, A.D. 1206–1227, which extended their general use throughout the nations of Islam." (*Jour. Soc. Arts*, p. 307, 28th February 1879.)

In looking around for authentic examples that may with propriety be attributed to the period of Arab rather than Turkish ascendancy, those of Egypt appear most accessible, yet even here little remains of this earlier age. In the introduction to the catalogue of exhibits at the National Museum of Arab Art, located in Cairo, Max Herz Bey writes:—"Although the conquest of Egypt by the Saracens was completed in 641, we have no Arab monument, still standing in its original form, of an earlier date than 876. During these

two hundred and thirty-five years of artistic silence, Egypt was merely a province . . . . and no temporary governor, except its first conqueror, cared to waste upon it the wealth and labour necessary for great monuments. Where no monuments are built, Arab art cannot flourish; for to the Saracens architecture was *the* art *par excellence.*" (*Catalogue, Arab Museum*, Quaritch.)

Herz states that 'Amr's great mosque, founded at the conquest for the new capital El-Fustāt, has so often fallen to ruin and been restored, that scarcely anything of the original building can be proved to remain. He then proceeds to describe many mosques erected near Cairo, from A.D. 868 downward, but we find little about glazed tiles referable to a period earlier than the thirteenth century.

What perished when El-Fustāt was burned A.D. 1168 cannot now be known, though Herz trenchantly observes that "The potter's art was assiduously cultivated in Egypt from very early times, and it was certainly not allowed to deteriorate during the Mohammadan period . . . almost a history of the art could be traced, by means of the numerous fragments, from the commonest domestic crockery to the finest decorative work, daily picked up among the rubbish mounds which mark the site of the old city of Fustāt (near 'old Cairo'). . . . . The glazed faïence forms a rich series worthy of more careful study than it has hitherto received." (*Catalogue, Arab Museum*, p. 64, Quaritch.)

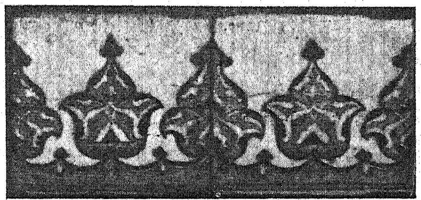


FIG. 56.—Border tiles, Mosque el Azhar. Arab Museum, Cairo. (*Photo by Lekegian & Co., Cairo.*)

Buildings and ruins of buildings are the only promising fields of research for examples of early Saracenic glazed tiles, for, as Stanley Lane-Poole says, "all Saracenic art is decorative or subsidiary to architecture . . . . inlaid doors, sculptured stone, and plaster ornament . . . . marble mosaic and other substantive parts"; also, even detached objects like enamelled glass lamps, and exquisite filigree bronze tables inlaid with silver, "however beautiful in themselves, were strictly connected with some mosque and in harmony with its decorative style." (*Catalogue, Arab Museum*, p. 11, Quaritch.)

In commenting upon individual specimens in the museum, Herz further states that "The Arabs, unlike the Persians, made but a sparing use of wall-tiles in their decoration; but this is explained, no doubt, by their preference for marble, which was readily obtained in Egypt, or near by, and which in the form of mosaic produced a richer effect than tiles could give. In this preference they followed the Romans. As a matter of fact, the only monuments of Arab rule in Egypt which are decorated with tiles are the minarets of the mosque of En-Nâsir in the citadel (1318), the tomb of Tashtemir, the cup-

bearer (1334), and the tomb called that of the Khawand Baraka. In the minarets of En-Nâsīr the tiles are of single colours, white, brown, and green. . . . . The cupola of Tashtemir has a band of green tiles in the drum. That known by the name of the Khawand Baraka . . . . has on its cupola a course of tiles forming an inscription. . . . . The large white letters stand boldly out of the ground, which is of two shades of green, and set off by foliage in dark brown faïence." (*Catalogue, Arab Museum*, p. 66.)

But both in his chronology, p. xvi, and in the introduction, p. xxvi, Herz Bey has shown that the Mamlūks seized the government of Egypt, and overthrew that of the Arabian princes A.D. 1250, and he classes the medresa of En Nâsir as Mamlūk; so that even these would appear more appropriately to fall into the category of Tartar and Turkish.

How far the Arabs deserve to be credited with the arts they encouraged must ever, apparently, remain a subject for discussion; but W. De Morgan has very forcibly pointed out that "however ready we may be to ascribe a Persian parentage to the arts of the Arabs, we cannot shut our eyes to the fact that the area of Arab conquest in the ninth century is almost exactly co-extensive with the distribution of the manufacture of lustres, so far as it is known to us, in the twelfth." (*Jour. Soc. Arts*, 24th June 1892, pp. 756–767.)

Sir George Birdwood, M.D., K.C.I.E., asserts that "There is no Arab art, not even in Arabia, and to this day all the Arabesque embroidery of Egypt and Syria is done by Greek tailors. . . . . They [the Arabs] were nothing more than the diffusers of the science and art received by them from the Greeks." (*Jour. Soc. Arts*, 24th June 1892.)

But even if the Arabs were merely diffusers of knowledge—and few of us are more—that of itself is not altogether unworthy of praise. Indeed, Tytler expresses admiration for them on that account. He wrote:—"The first restorers of learning in Europe were the Arabians, who, in the course of their Asiatic conquests, becoming acquainted with some of the Ancient Greek authors, discovered and justly appreciated the knowledge and improvement to be derived from them. The caliphs procured from the eastern emperors copies of the ancient manuscripts, and had them carefully translated into Arabic, esteeming principally those which treated of mathematics, physics, and metaphysics. They disseminated their knowledge in the course of their conquests, and founded schools and colleges in all the countries they subdued. The western kingdoms of Europe became first acquainted with the learning of the ancients through the medium of those Arabian translations. Charlemagne caused Latin translations to be made from the Arabian, and founded, after the example of the caliphs, the Universities of Bononia, Pavia, Osnaburg, and Paris." (*General History*, p. 329.)

Turkish or Tartar-Mohammedan.—Originally the Turks or Turcomans are believed to have been a Scythian or Tartar race, inhabiting a country

between the Black Sea and the Caspian, and to the north of Thibet, for they appear to have harassed the Chinese on one side and the Europeans on the other.

About the seventh century A.D. some of these Turks are said to have been employed as mounted mercenaries by the Christian emperor of Byzantium. Later, Saracen caliphs employed them in a similar capacity, and converted them to Mohammedanism. Gradually the Turks acquired power, and, ultimately throwing off Saracen authority, established a separate government. About A.D. 1043 they are stated to have subdued Persia, and in 1055 they took Bagdad and overthrew the Saracen caliphs. (Tytler's *General History*, p. 282, Simpkin.)

During the eleventh century the Seljukian Turks under Soliman, son of Cutulmish, invaded Asia Minor and founded the dynasty of the Seljuks, A.D. 1074.

These movements plausibly account for the examples of decorative tile-work found in Anatolia, Armenia, and the Caucasus. Other speculations are possible, as, for instance, that the Persians were not the only nation who cherished traditions of Babylonian and Assyrian ceramics. The art of enamelling bricks, which evidently travelled eastward *via* Susa, may also have trekked north into Armenia and the Caucasus, and there have been tentatively exercised and preserved.

Indeed, Fortnum, when describing five cups of Anatolian ware in the Ashmolean Museum, Oxford, remarks upon the strong affinity between the early alkaline-glass glazed wares of Egypt and Babylon, and the potter's productions of Persia, Damascus, and Anatolia, during the Middle Ages and following centuries; although at the same time mentioning a plate of Kutayan ware, decorated with a pattern of foliated sprays in dark blue on white ground, the latter probably of sixteenth-century work.

A scrutiny of M. Texier's list, pp. 86 and 87, *Traité des Arts Céramiques*, shows that he attributed the monuments of Konieh (Anatolia) to the eleventh or thirteenth centuries; those of Tabriz (Azerbijan) to the twelfth century; and the faience-ornamented minaret at Nicea (Bithynia) and the memorial tomb of Mohammed I. at Broussa (Bithynia) to the fourteenth century.

Brongniart states that Texier believed the ornamentation of the buildings at Konieh (Anatolia) with enamelled work was not anterior to the time of Sultan Kilidji-Arslan, who reigned in 1074 A.D. He supposes this prince or his successors obtained artists either from Arabia or Persia, who were able to cover the structures with enamelled tiles; and that these Seljuk princes established works for the manufacture at Nicea and at Broussa.

General Sir Charles Wilson, in a letter to Mr. W. Simpson about the remains at Konieh, wrote:—"It may interest you to know that in Anatolia there is much mud-building; and that most of the great buildings of the

Seljuks, more especially their great palace at Konieh, were of mud faced with glazed tiles. Some of the minarets of their mosques, built with sun-dried bricks, arranged in patterns and faced with glazed tiles, or with the ends of the bricks glazed, are extremely beautiful in their decay. The Seljuk architecture is Persian with a development of its own." (*Jour. Soc. Arts*, p. 903, 3rd June 1892.)

Brongniart, quoting from the writings of Dubois de Montperreux, tells of the gate of a castle at Nakhtchevan in Armenia, which is decorated with mosaic composed of enamelled bricks, the date of the erection being between 1146 and 1225. He also tells us that in the fortress of Erivan (Russian Armenia) may be seen a mosque of the eleventh century now converted into a Russian church, the dome and façade of which are covered with enamelled bricks arranged as mosaic. (*Traité des Arts Céramiques*, vol. ii. pp. 87, 88, 106.)

About this period occurred the horrors of the "Crusades," in connection with which it has been computed that upwards of 2,000,000 Europeans were buried in the East.

In A.D. 1227 there was another great disturbance in Asia. Gengiskan (or Chingiz Khan) with his Tartars broke down from the north upon Persia and Syria, massacring all who opposed them, whether Turk, Jew, or Christian.

But by A.D. 1300 the Turks had so far recovered from these shocks and reverses that Othman was then able to lay the foundation of the Turkish empire, and assumed the title of Sultan. To the period immediately succeeding this event the erection of the memorial tomb of Mohammed at Broussa (Bithynia) is assigned. In describing the decorative faience employed upon this monument, Jacquemart wrote:—"The casing tiles placed on the exterior . . . . were moulded in relief and painted, a special mode of decoration applied, as it is said, for the first time. The ground is a metallic brown; some with scrolls in reserve have fine projecting inscriptions in blue . . . . other tiles present arabesque combinations, the outline of which described by a *cloisonné* line encloses coloured enamels. . . . . In the interior the arched roofs and ceilings are decorated with monochrome pieces describing vast mosaics." (*History of the Ceramic Art*, p. 114, Sampson Low, etc.)

In 1402 the Turks again suffered temporary defeat and eclipse at the hands of the powerful Usbek Tartar prince, Timur-bek or Tamerlane, a descendant of Gengiskan, who established a capital at Sarmarcand, where, though illiterate himself, he encouraged learning and refinement. (Tytler's *General History*.) After the death of Tamerlane, the Turks again recovered power and resumed their designs on the Christian empire, whose capital was Byzantium. On 25th May 1453 they assailed and took the city, its emperor, Constantine II., being slain in its defence. Thus ended the Byzantine power, which had existed 1123 years. Thus also Christianity received possibly the

severest blow ever delivered against it by an opposing sect; which, in conjunction with the earlier destruction of the Christian power in Egypt, vastly reduced the area of its influence.

Thenceforward the Turks became a powerful and united nation. In the sixteenth century they invaded Egypt and overcame the Mamelukes—a race of Circassians who, as we have already seen, had, in A.D. 1250, put an end to the government of the Arabian princes in Egypt and seized the power themselves.

Seven centuries of such alternating service and supremacy under the influence of Mohammedanism resulted in the modern Turk or Osmanli—an outcome of much racial fusion, yet still retaining characteristic antipathy to personally engaging in manufacture.

The arts being left very largely in the hands of subjected races, partake so strongly of characteristics indigenous to the country concerned as to be practically indistinguishable from what immediately preceded. Hence, in some museums art products of this period from several countries are classed as Turkish.

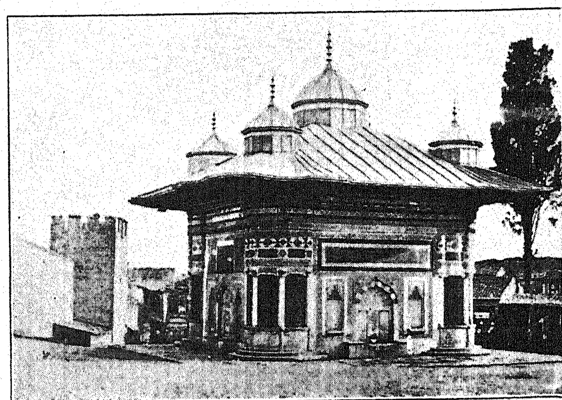


FIG. 57.—Kiosk at Constantinople.

The two examples of Turkish tilework on Plate X., one of the fifteenth and the other of the sixteenth century, kindly selected by C. Stanley Clarke, Esq., of Victoria and Albert Museum, as typical ones for illustration in this volume, with the sanction of the Director, Sir C. Purdon Clarke, C.I.E., should be referred to.

By the same authority we are permitted to illustrate a fine example of Turkish ceramic art of the eighteenth century, in the shape of a fireplace, now in the Victoria and Albert Museum. This is officially described as of "enamelled earthenware tiles, consisting of a pyramidal hood with wavy arch beneath, surrounded by a setting enclosed within a border. The tiles are painted in red, blue, and green on a white ground, with floral scrolls and wavy leaves placed diagonally, enclosing spaces ornamented with Chinese clouds and three circles. The borders are decorated with leaves and flowers united by intertwining stems. On either side of the point of the hood is a very large boss. The front of the hood is further decorated with seven medallions inscribed with the names of the seven sleepers." This piece was

formerly in the palace of Fuyad Pasha at Constantinople, and is dated A.H. 1143 (=A.D. 1731). The palace was burnt down in the great fire of 1857, and it is to the credit of ceramics that this interesting object escaped destruction.

Turning once more towards Egypt, Herz Bey, the chief architect of the commission of Arab monuments, asserts that the richest and most flourishing period of Saracenic art and architecture was that of the Mamlūk Sultāns of the Bahry or Turkish dynasty (1250–1382). In support of this he then proceeds to quote from Stanley Lane-Poole's *Cairo Sketches* as follows:—"The Mamlūks offer the most singular contrasts of any series of princes in the world. A band of lawless adventurers, slaves in origin, butchers by choice, turbulent, bloodthirsty, and too often treacherous, these slave kings had a keen appreciation for the arts, which would have done credit to the most civilized ruler that ever sat on a constitutional throne. Their morals were indifferent, their conduct violent and unscrupulous; yet they show in their buildings, their decoration, their dress, and their furniture, a taste and refinement which it would be hard to parallel in Western countries even in the present æsthetic age. It is one of the most singular facts in Eastern history that wherever these rude Tartars penetrated, there they inspired a fresh and vivid enthusiasm for art. It was the Tartar Ibn-Tulūn who built the first example of the true Saracenic mosque at Cairo; it was the line of Mamlūk Sultāns, all Turkish or Circassian slaves, who filled Cairo with the most beautiful and abundant monuments that any city can show." (*Cairo: Sketches of its History, Monuments, etc.*, pp. 95–97.)

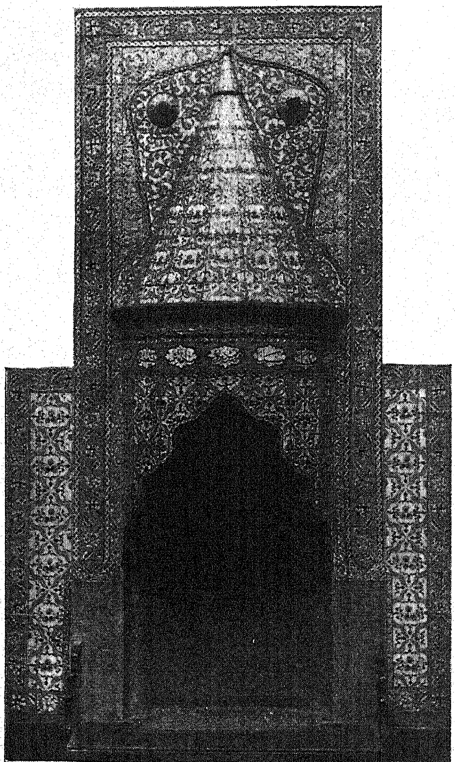


FIG. 58.—Turkish fireplace. V. and A. M. (*By permission.*)

Herz Bey then continues:—"There was a transitional period, at first, before the true Mamlūk architectural style was formed. In the mouldings of the great mosque of Ez-Zāhir Beybars (1268), the façades of Kalāūn's monuments, etc., we have signs of exotic influences; whilst the Gothic portal from a church at Acre, bodily transported to form the doorway of the medresa

of En-Nāsir in the Sūk-en-Nahhāsīn, shows alike an appreciation of foreign styles and an indifference to artistic consistency. But these exotic influences from Syria and elsewhere soon found their true place, and became assimilated, so far as they were harmonious, in the rapidly developing Mamlūk style. The long reign of over forty years (1299–1341) of En-Nāsir Mohammad, son of Kalāūn, gave time for the work of selection, adaptation, and precision, to which the admirable style of the numerous mosques erected by En-Nāsir, his sons, and the officers of his court, bear witness. The abounding energy of this productive epoch bore the happiest results for art. The hesitating experiments of the earlier period gave place to a rare distinctness of architectural conception. Despite a remarkable variety and incomparable wealth of form and combination, the unity of design stands clearly out and reveals a finished and singularly adequate style. In the arrangement of the façade . . . . the larger surfaces are given perspective by a system of high shallow niches in which the windows are set in double rows; these niches are brought back to the face above by stalactite cornices, and the portals, though wider and deeper, are treated in the same way, and richly coated with marble. . . . . The wainscots or dado are of marble mosaic, often to the height of several yards, and the pavements are tessellated in bold and striking mosaics. The rich and harmonious effect of the interior is enhanced by the panelled and inlaid pulpit . . . . and enamelled glass lamps. And from the few remains that have come down to us . . . . it is clear that the palaces and private houses of the Mamlūk age hardly fell short of the mosques in the beauty and elaboration of their form and decoration." (*Catalogue of Arab Museum*, pp. xxvi–xxix, Quaritch.)

FIG. 59.—Tile in Arab Museum (222), Cairo. (*Photo by Lekegian & Co.*)

Mr. Stanley Lane-Poole expresses the opinion that tiles made from about A.D. 878 to 1516, whether Indian, Persian, Syrian, or African, should be all grouped as Saracenic. Of these he gives the palm to those of Egypt. To use his own delightful phraseology:—"The mosques of Cairo furnish a fuller, longer, and more continuous record of the arts employed in their construction and decoration than any other series of monuments in a single Mohammedan city, and the simple lines and restrained decoration of the Egyptian artists exhibit to perfection the essential character of the Saracenic art." (*Art of the Saracens in Egypt*, preface, Chapman & Hall.)

Marble mosaics, enriched with mother-of-pearl and blue and red ceramic tesseræ of minute delicacy, were placed as a dado, 4 feet high, along the interior walls of mosques and principal houses. (*Ibid.*, p. 104.)

About the thirteenth century, he tells us, glazed painted tiles were introduced; but that the coating of the remarkable minarets of the mosque of En-Nāsir-Mohammad, in the citadel of Cairo, is of glazed blue tiles, which carries them back to the first quarter of the fourteenth century.

Of the mosque of Aksunkur, Mr. Lane-Poole avers that "no more splendid example of the use of tiles in large surfaces can be seen in Cairo," and that "It is impossible to give any idea of this magnificent wall, covered with tiles from top to bottom, and displaying the typical Cairene pattern of blue flowers and leaves in the utmost perfection." (*Ibid.*, p. 237.)

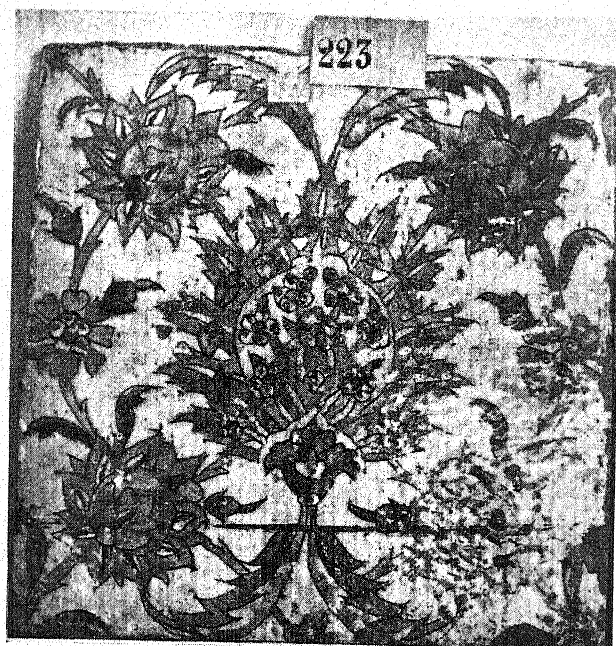


FIG. 60.—Tile in Arab Museum (223), Cairo. (*Photo by Lekegian & Co.*)

From the same authority we learn that this mosque was built about 1347 A.D., of stone with a vaulted roof and a pavement of marble. Later, a fountain was added by Amir Inghān. This was covered by a roof resting on marble columns.

Continuing, Mr. S. Lane-Poole says:—"But the historian (El-Makrizy) provokingly says nothing about the tiles, and we are forced to believe that, as he could hardly have omitted to mention so salient and almost unique a feature if it had existed in his time, the tiles must have been inserted when Ibrāhim Aghā restored the mosque in 1652." (*Art of the Saracens in Egypt*, p. 237, Chapman & Hall.)

Max Herz Bey, also, when referring to the mosques of Aksunkur and of Amir Sheykhū, writes that these "have sometimes been cited as examples of the early use of wall-tiles; but a glance at the latter will show that the tiles are mixed up without any method with the remains of the original marble

FIG. 61.—Panel of tiles, eighteenth century. Arab Museum, Cairo. (*By permission of Max Herz Bey, curator. Photo by Lekegian & Co., Cairo.*)

mosaic work, and there is no doubt that the tiles which line the līwān of Aksunkur were placed there by the restorer Ibrahīm Aga. The tiles of both mosques, too, are not of the simple Arab style; they are Turkish." (*Catalogue, Arab Museum*, p. 68, Quaritch.)

Splendid illustrations of the tilework of the Mosque of Ibrahīm Aga, or of Aksunkur, may be found in M. Prisse d'Avenne's *L'art arabe*, a copy of which may be consulted in the City of Birmingham Reference Library.

Hispano-Moresque.—"A nation . . . . without a legitimate country or a name. A remote wave of the great Arabian inundation cast upon the shores of Europe": so wrote Washington Irving, of the Moors.

After the conquest of Egypt, the Saracens spread rapidly along the northern coast of Africa, and ultimately established themselves, none too securely perhaps, in Morocco. To their restless ambition Andalusia offered temptation, and in A.D. 675 they invaded it and were repulsed. In A.D. 711 a second attempt was more successful, and eventually resulted in the establishment of Moorish supremacy in Southern Spain. Years of strife followed, both among themselves and with neighbouring Christian states; but they gradually gathered power.

Under Abd-er Rahman, about A.D. 760–770, they cast off allegiance to the Syrian caliphs, and he established himself as King of Cordova. Thereafter the city of *Cordova* became a seat of refinement and civilization, with which, excepting only Byzantium, no city in Europe could compare. Plants and seeds and gardeners were brought from Syria to fill Cordova with Eastern luxuriance. Its palace roofs rested upon marble columns and its floors were inlaid with mosaics. By repute there were 50,000 houses of the aristocracy, 100,000 or more dwellings, 800 schools, 700 mosques, 900 public baths, 50 hospitals, and a library of 600,000 books—all this, be it remembered, when our Saxon forefathers dwelt in wooden hovels and trod on dirty straw. The noble mosque is still a wonder and delight to travellers: splendid glass mosaics, which artists from Byzantium came to make, still sparkle like jewels in the walls. (*Spanish Pictures* and *The Moors in Spain*.) Art, literature, and science prospered at Cordova, and students from France and Germany and England came to drink at the fountains of learning there. Yet, notwithstanding all this grandeur, nothing in the shape of decorative faience is mentioned in connection with this period. Glass and marble mosaics were the nearest approach.

Toledo, another city, also rose to prosperity under the Moors. During their supremacy Christians were protected and allowed to own property and to exercise their faith; and Jews were even permitted to share in the administration of public affairs. The latter became so numerous that two synagogues were built—one in the ninth century, which eventually fell into disuse; the other in 1357 A.D., by Samuel Levy, treasurer to Don Pedro the

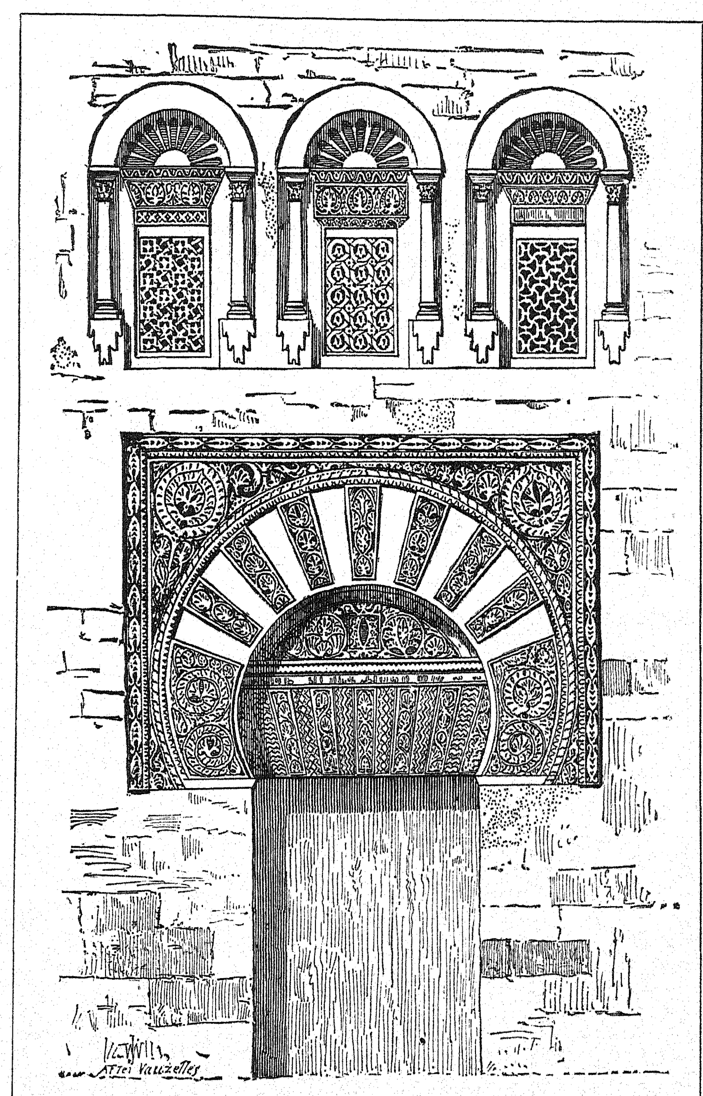
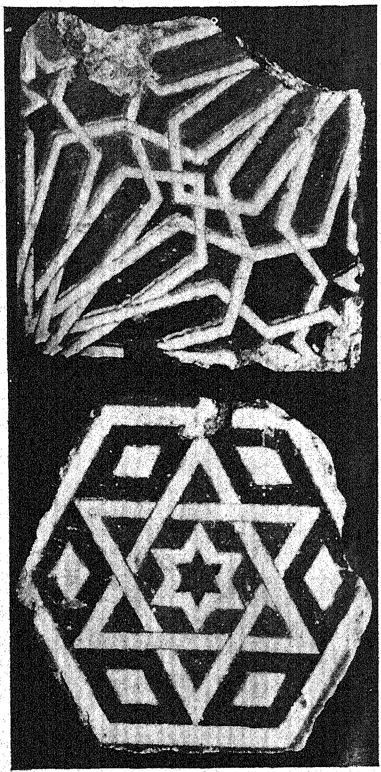
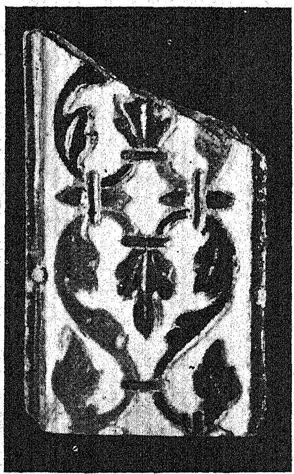


FIG. 62.—Gate of mosque at Cordova. (See *Moors in Spain*, p. 137. *By permission of T. Fisher Unwin, London.*)





FIGS. 63 AND 64.—Tiles from synagogue, Toledo. (J.W. Coll.)

Cruel. That would, of course, be after the reconquest of Toledo by the Christian powers (A.D. 1085). The ornamentation of the ceiling and walls of the last-named synagogue are said to have been delicate and beautiful.

John Ward, Esq., F.S.A., who visited Toledo, in company with Sir Henry Doulton, in April 1879, has most courteously granted the author permission to examine and illustrate three enamelled tiles he obtained from one of these synagogues.

The body of the larger pieces (fig. 63) is pale buff, that of the smaller piece (fig. 64) is pale red colour; the large square tile seems to have originally measured about $5\frac{1}{2}$ inches by $5\frac{1}{2}$ inches by 1 inch. The enamels are excellent, and are applied in *cloisonné* style, in black, green, ochre, and white colours; apparently directly upon the body itself, without engobe. All except white and black are almost transparent, yet richly coloured, very effective, and adhering perfectly.

The designs are Moorish rather than Gothic, perhaps excepting fig. 64. This may be accounted for by the probability that, although Toledo had been recovered from the Moors by combatant Christian forces, amicable relations may have existed at intervals between the civil populations.

Mr. Ward explains the circumstance in another way, namely, that the Jewish synagogue was originally a Mohammedan mosque; but when the Moors were driven out of Spain, the Jews, having been allies of the Christians, were given the building for their religious worship.

Seville, too, provides remarkable relics of the Moors. It is said that it was Julius Cæsar who originally raised this city to importance by making it the capital and designating it Romula (Little Rome); it

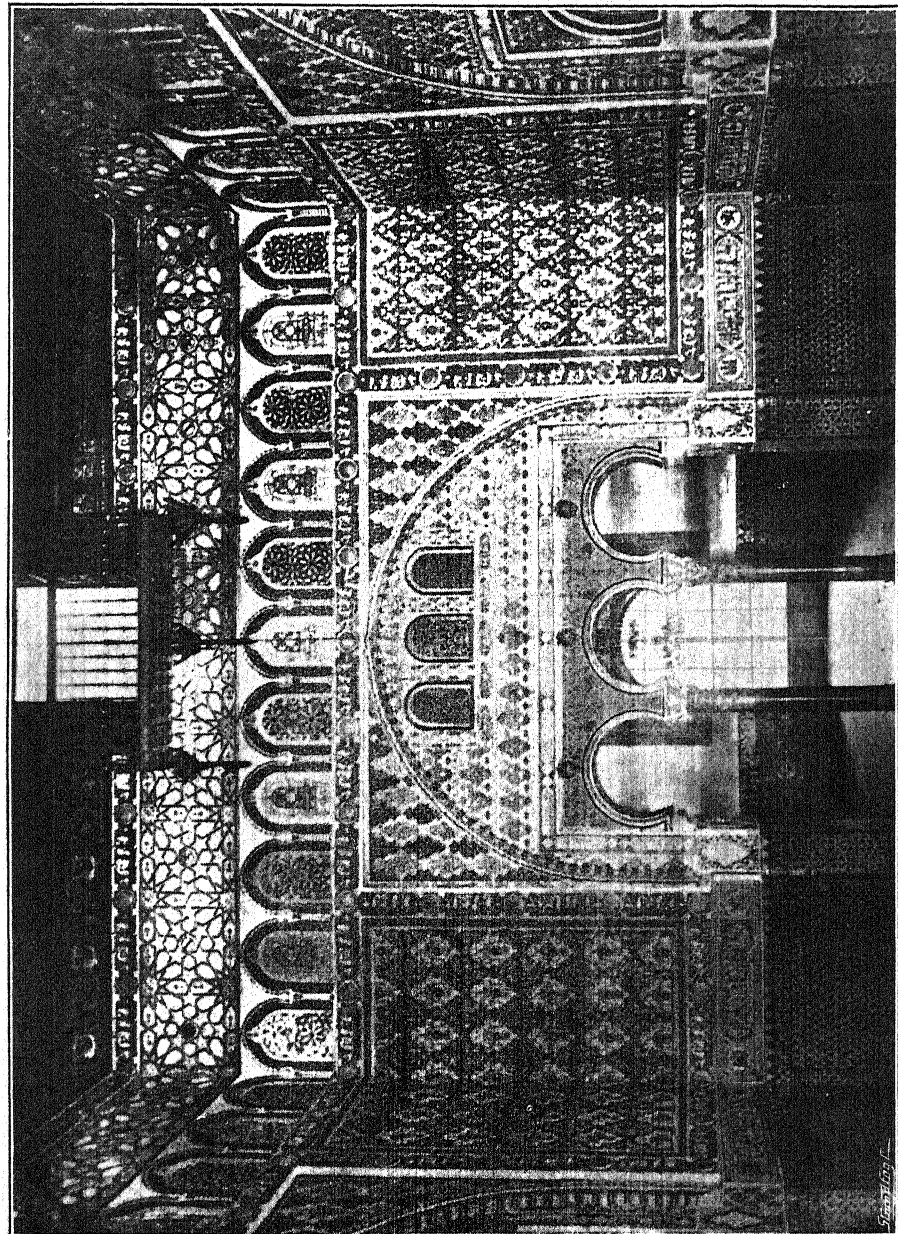


FIG. 65.—Hall of Ambassadors, Alcazar, Seville. (*By permission of the Board of Education and of the editors of the "Architectural Review."* See *Arch. Review*, April 1902, p. 119.)

would therefore, in all probability, be a flourishing city long before the advent of the Saracen. "By far the finest relic of purely Moorish architecture in the city is the tower of the Giralda," wrote Dr. S. Manning. (*Spanish Pictures*, p. 159, R.T.S.)

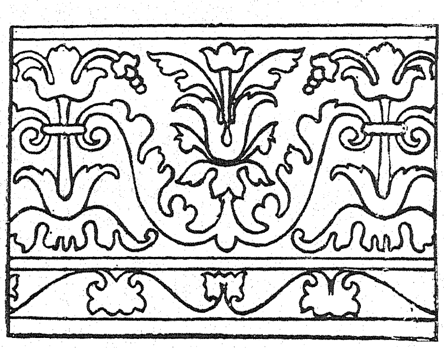


FIG. 66.—Seville. Sixteenth century. (Forrer Coll., 11.)

On the other hand, it is perhaps equally true to assert that its most brilliant example of the decorative use of tiles is found in the Alcazar. Strictly speaking, perhaps, these tiles should not be classed as Moorish, because whatever the Alcazar was originally, it was rebuilt by Pedro, after the expulsion of the Moors from Seville, and the tiles were of the later period, say about 1360 A.D. But as the Alcazar of Seville is probably little more than an imitation of the Alhambra of Granada, and is reputed to have been reconstructed under the direction of the architects and builders who built the Alhambra, there is, after all, some plausibility in considering the work, from an artist point of view, inseparably associated with the Hispano-Moresque. Indeed, Halsey Ricardo asserts that "the Spaniards took over the potting business of the Moors as a going concern."

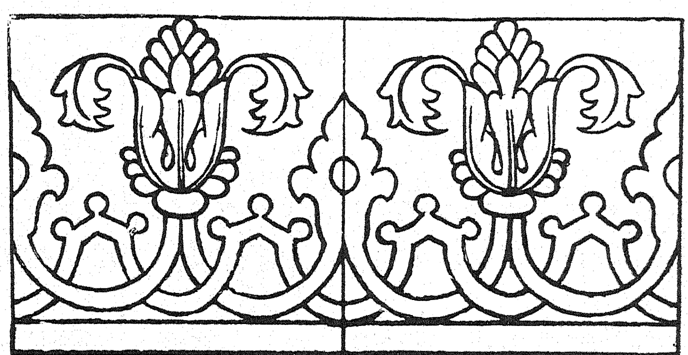


FIG. 67.—Madrid. (Forrer Coll., 10.)

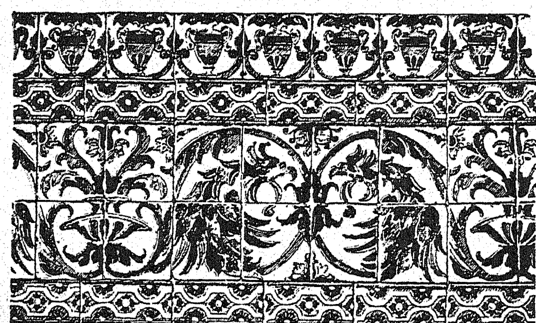


FIG. 68.—Calatayud. (Forrer Coll., 12.)

Dr. Forrer, in his *Geschichte der europäischen Fliesen-Keramik*, has several remarkable coloured plates illustrating Hispano-Moresque tilework, his plates 32,

36, 43, 45, 46 being especially attractive illustrations. Of his uncoloured illustrations we are permitted to reproduce examples of sixteenth-century work from Seville (fig. 66), of work of the same period from Madrid (fig. 67), and of the later Renaissance period (fig. 68) from the Castle Ram, near Calatayud, being a relief-work panel.

Selected examples from Dr. Forrer's coloured plates of Spanish tilework are, by permission, reproduced by the three-colour block process on Plate XI.

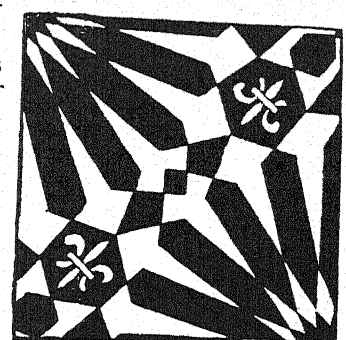


FIG. 69.—Enamelled tile from Madrid. Sixteenth century. (Forrer Coll.)

Alderman W. R. Barker, of Bristol, in his book on *St. Mark's, or The Mayor's Chapel* of Bristol, mentions that the floor of the Poyntz Chapel there is laid with a mosaic of Spanish enamelled tiles, said to be similar to those in the Alcazar of Seville, and of the time of Charles V. They are supposed to have been imported by a Bristol merchant, or brought over by Sir Francis Poyntz about the year 1527. These tiles are probably unique, so far as England is concerned, and have always attracted much attention locally.

Granada.—About A.D. 1090 the power of the Moors began to wane, and the Christians of Northern Spain pressed them closely. Assistance was obtained from Northern Africa, but these eventually turned upon the original Moors of Spain and took the government in their own hands. Various changes took place, and by A.D. 1260 the Moors had been forced back until they were restricted to the single province of Granada. Here for two and a half centuries they made their last stand in Spain. Not an inglorious stand either, if what we read is true; for Mr. Prescott writes:—"The Moorish territory of Granada contained within a circuit of about 180 leagues all the physical resources of a great empire. Its broad valleys were intersected by mountains rich in mineral wealth, whose hardy population supplied the State with husbandmen and soldiers. Its pastures were fed by abundant fountains, and its coasts studded with commodious ports, the principal marts in the Mediterranean. In the midst, and crowning the whole as a diadem, rose the beautiful city of Granada. . . . On the summit of one of the hills of the city was erected the royal fortress or palace of the Alhambra, which was capable of containing within its circuit 40,000 men. The light and elegant architecture of this edifice, whose magni-

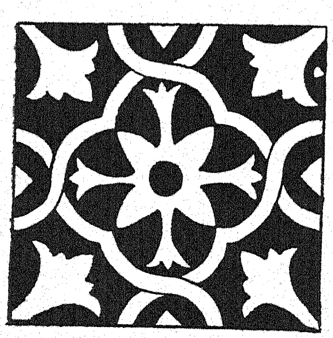


FIG. 70.—Enamelled tile from Barcelona. Sixteenth century. (Forrer Coll.)

ficent ruins still form the most interesting monument in Spain . . . . shows the great advancement of the art since the construction of the celebrated Mosque of Cordova. Its graceful porticos and colonnades, its domes and ceilings glowing with tints which in that transparent atmosphere have lost nothing of their original brilliancy, its airy halls, so constructed as to admit the perfume of surrounding gardens . . . . its fountains which still shed their coolness over its deserted courts, manifest at once the taste, opulence, and sybarite luxury of its proprietors. . . . . The reputation of the citizens for trustworthiness, says a Spanish writer, was such that their bare word was more relied on than a written contract is now among us." (*Spanish Pictures*, p. 134, R.T.S.)

The fortress-palace Alhambra is also described in glowing terms by Washington Irving and by Rev. S. Manning. Of its tilework the Rev. Hartwell Horne wrote:—"The lower part of the walls, to the height of about 4 feet, is covered with porcelain mosaics of various figures and colours; and it appears, from a few remaining fragments, that the floors and columns of some of the apartments were also covered with similar mosaics. The Arabs took great pleasure in these decorations, a luxury unknown to their Gothic contemporaries, who skirted their halls with mats and covered their floors with bulrushes."

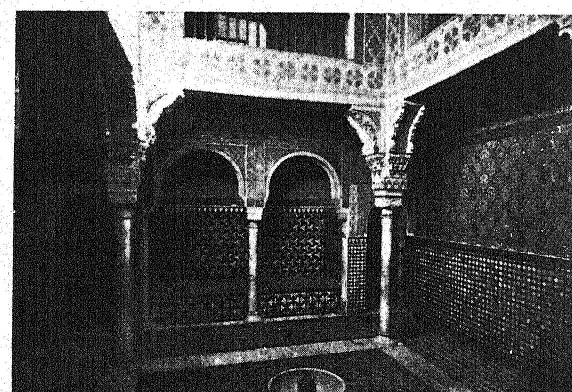
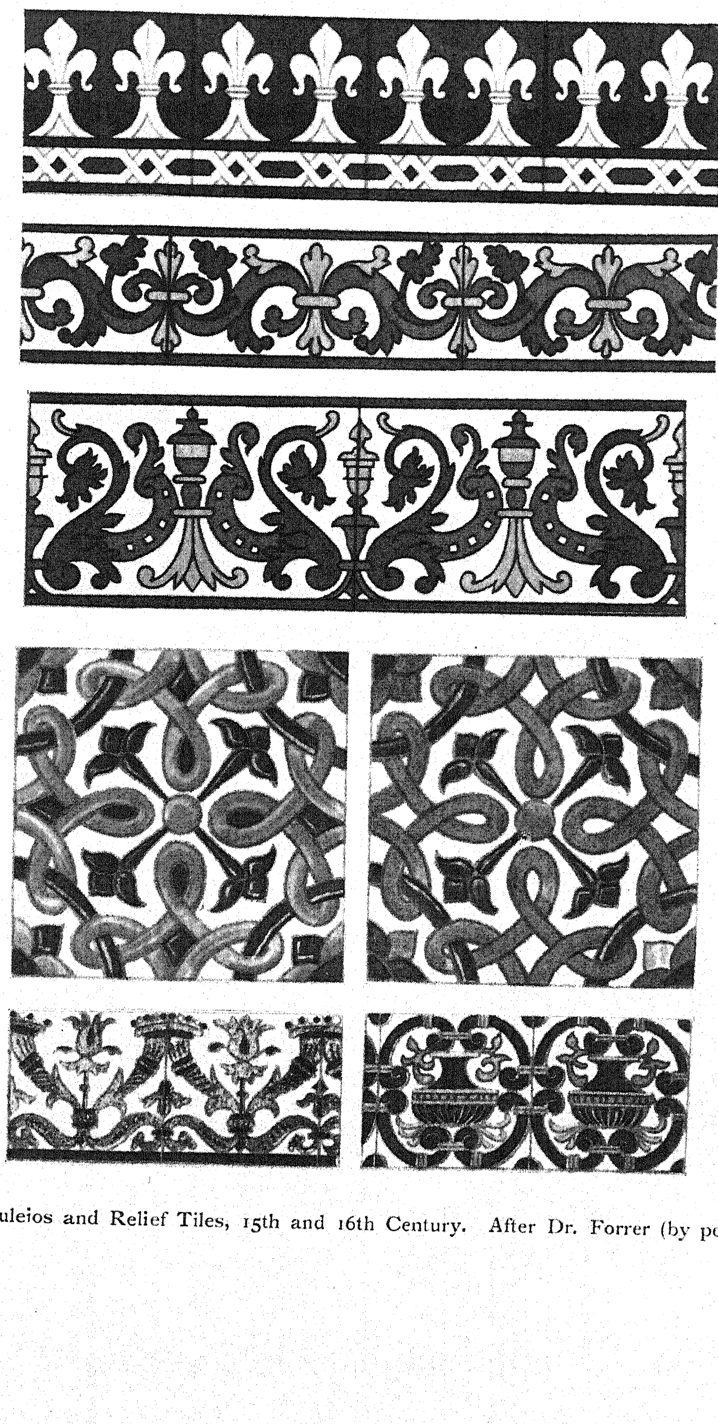


FIG. 71.—Room of the Divans, Alhambra, Granada. (*From photograph in S.K.M., by permission.*)

Mr. Lewis F. Day, in like manner, speaking of the tilework of the Alhambra, comments upon its mosaic character thus:—"He did not think people realised how entirely it was mosaic. He himself did not until he went to Spain. Practically all the Moorish tilework in the Alhambra was a mosaic of bits of tiles." (*Jour. Soc. Arts*, 24.1.1902, p. 167.)

How far the Moors themselves executed the decorative work in the Alhambra is very uncertain. Sir R. Murdoch Smith observed that a "peculiar pendent ornamentation of vaults and niches, of which the Alhambra is so typical an example, is identical in style with that used throughout Persia down to the present day; and specimens of which in plaster have been found in the ruins of Rhages, a city finally destroyed six hundred years ago." On the other hand, he says:—"The Arabs themselves were probably never an



Spanish Azuleios and Relief Tiles, 15th and 16th Century. After Dr. Forrer (by permission.)

artistic people, although many of their rulers were . . . . patrons and propagators of art and science." "It is far from improbable," he continues, "that even the Alhambra itself was chiefly the work of Persians, who stood to the Arabs in much the same relation that the Greeks did to the Romans. The presence of a considerable colony of Persians in Spain, in the time of the Moors, is attested by numerous documents still in existence." (*Persian Arts*, p. 4, Chapman & Hall.)

Mr. W. De Morgan observed two distinct periods of manufacture in the tiles of the Alhambra. He said:—"The old tiles with which its walls are covered are genuine native azulejos of the date of the completion of the building, about A.D. 1350. They must be distinguished from those placed in the building when it was restored by Charles V. in the sixteenth century. They belong to the same group of manufactures as the great jars which were found full of coin under the building. . . . These, and one or two others, are the oldest surviving examples of the practice of lustre in Spain. There does not seem to be any need to assume that they were imported from Cairo or Persia, and we may probably ascribe their manufacture to Malaga. The Alhambra tiles may have been made there too; although, in view of the comparatively simple operations involved in the making and firing of the latter, and the vast quantity required, it might be more reasonable to suppose that they were made on the spot." (*Jour. Soc. Arts*, 24.6.92, p. 757.)

Again, with special reference to the very early period of Saracen and Moorish supremacy in Spain—about 900 to 990 A.D.—Mr. De Morgan remarks:—"The course of the Arabs, from Cairo to Tangier, has been said to be traceable by the glazed and decorated wall-tilings of their buildings. . . . This is in some sense true, but it has been more than once told, so as to convey a false impression that the Saracen invaders of Africa built tile-kilns at every station of importance, and that pottery factories were at work in Spain, if not during the time of the Abbasides, at any rate very soon after the establishment of the Caliphate of Cordova. Wall-tiles, beautifully decorated, were placed by the historical imagination on the walls of the great mosque at that town, and by implication at Seville and Toledo also. But the tendency of more recent investigation is to ascribe all the surviving examples of Arab wall-tiling in Spain to a much later date. . . . The construction of the mosque was still going on in the time of the Vizier Almansor, who melted up the bells from the shrine of Compostella to make lamps for the mosque. . . . This was in 985. But if we judge by contemporary descriptions of buildings, these great mosques, and others, such as the palaces of Az-Zahra, at Cordova, were marvels of decoration in marble, gold, and ivory, but were entirely without wall-tiling. Moreover, mosques of the same period, at Cairo and elsewhere, are entirely without tile-decoration." (*Jour. Soc. Arts*, 24.6.92, p. 757.)

In the *Handbook to the Museum of Practical Geology, London*, reference is made to the fact that the Moors introduced their lead glaze in Spain in the thirteenth century.

Again, Señor Juan Riaño notes that soon after the fall of the caliphate, metallic lustred ware was made in Spain; and he tells us that Edrisi, an Arabic geographer of the Middle Ages, in describing Calatayud, wrote:—"Here the gold-coloured pottery is made which is exported to all countries." Now, Edrisi was born 1100 A.D., studied at Cordova, and finished writing his book in A.D. 1154.

Summarizing, then, we are led to the inference that three distinct styles of tilework for interior embellishment characterize Hispano-Moresque architecture, namely:—Firstly, ceramic tesseræ, associated with glass and marble tesseræ in the floor and wall mosaics, as used in the buildings at Cordova.

Secondly, mosaics of bits of glazed or enamelled tiles such as appear in the earlier decorative work of the Alhambra at Granada, of a date about A.D. 1350.

Thirdly, larger tiles covered with plumbo-stanniferous enamels, often associated with painted and lustre ornamentation, all of this subsequent to A.D. 1350.

Indian.—Authorities agree that a knowledge of art and science existed in India at a very early date. Romesh. C. Dutt, C.I.E., tells us that the Aryans were settled on the Indus and its tributaries two or three thousand years before Christ, and that the hymns of the Veda give a complete though fanciful picture of the arts, industries, and agriculture of the Indo-Aryan tribes, whose civilization forty centuries ago was the earliest form of civilization reared by the great Aryan race. Every considerable Aryan village, says Dutt, had its artisans in those days as now, and numerous references to arms, chariots, carts, ornaments, and domestic utensils show that they were in common use. About 1400 B.C. the Hindus of the Punjab extended their dominions, until the valley of the Ganges also was colonized, and eventually the newly acquired area excelled even the mother-country of the Punjab in wealth and power, and in learning, arts, and civilization. Thus in place of small states arose great and populous kingdoms, ruled over by august sovereigns. (*Civilization of India*, Dent & Co.)

But there was civilization in India before this. Sir George Birdwood, M.D., K.C.I.E., asserts that "When the Aryas made their way through Afghanistan and Cashmere into the Panjab, they found the plains of the Indus already occupied by a Turanian race, which they easily conquered, but which, as the caste regulations of the code of Manu prove, was far superior to themselves in industrial civilization. These aborigines already worked in metal and stone, wove woollen, cotton, and linen stuff, and knew how to dye them, and how to embellish their buildings with paintings." (*Industrial Arts of India*, p. 158.)

Hence it would seem that the art and learning of the Hindoos, *i.e.*, of the portion of the Aryan race settled in the districts around the Indus and its tributaries, had received its early impulse from a Turanian or yellow Mongolian race, of greater antiquity, who occupied India before them.

Hindu supremacy and religion eventually spread over the whole of India, and nearly all non-Aryan races were subjected. About 522 B.C. Gautama Buddha, a learned prince who had become dissatisfied with the trammels of priestly rules and rites, began to preach his newly found truth that "the salvation of man lay—not in sacrifice and ceremonials, nor in penances—but in moral culture and a holy life, in charity, forgiveness, and love." For forty-five years, Dutt tells us, Buddha preached and organized his new system, and thereafter for a thousand years Buddhist monasteries multiplied all over India. By the tenth century A.D., however, Buddhism had become practically exiled from India, and a modified form of the more ancient Brahmanism supervened. Thus it is that the earliest existing specimens of Indian architecture are the ruins of Buddhist churches and monasteries. (*Civilization of India*, p. 47, Dent & Co.)

But there appears to be no mention whatever of decorative ceramics in connection with these ruins. The reason is not far to seek, for Dutt informs us that "they are not *constructed* but *excavated* in rocks. Twenty or thirty churches are known to exist, and with one exception they are all excavated." . . . . "The most perfect specimen of this kind of architecture," he tells us, is "the church of Karli, excavated in the first century before Christ"; it "consists of a nave and side-aisles, terminating in an apse or semi-dome, round which the aisle is carried. It is 126 feet from the entrance to the back wall, and 45 feet 7 inches wide. Fifteen pillars on each side separate the nave from the aisles, and each pillar has figures of elephants on the top, with well-executed human figures on them. Above this springs the semi-circular roof, and the whole interior is lighted by one undivided volume of light coming from a single opening overhead." (*Civilization of India*, p. 60, Dent & Co.)

One of the far-famed temples of Ellora, of the eighth or ninth century A.D., is said to be situated in a vast pit, excavated in solid rock. In the centre stands the temple (the Temple of Kailasa), with a high tower, a large porch supported by sixteen columns, a detached porch, and a gateway, all carved out of the solid rock. (*Ibid.*, p. 73.)

Dr. Kennedy, writing of India many years ago, describes bricks he saw there, of unequalled quality. He wrote:—"Nothing I have ever seen has at all equalled the perfection of the early brickmaking which is shewn in the bricks to be found in these ruins [ancient tombs on the Makli range of hills near Tatta, in Sind],—the most beautifully chiselled stone could not surpass the sharpness of edge and angle and accuracy of form, whilst the substance was

so perfectly homogeneous and skilfully burned, that each brick had a metallic ring, and fractured with a clear surface like breaking freestone. I will not question the possibility of manufacturing such bricks in England, but I must doubt whether such perfect work has ever been attempted." (*Pict. Gallery of Useful Arts.*)

But sculpture and carving seem to have been the strong point of ancient Hindu architecture; for instance, the tower of the great Temple of Bhuvaneswar, we are told, is 180 feet high, and is completely covered with elaborate carving and sculptures, upon which infinite labour has been bestowed. (*Civilization of India*, p. 71.)

The Dravidian style of architecture, which is perhaps not only pre-Mohammadan, but in essence, also, pre-Aryan, *i.e.* pre-Hindu, is exemplified in Southern India. The Dravidians, however, were not the aborigines, but, like Aryans, were early immigrants from Central Asia; and to their credit it is said of their descendants, who are a dark-skinned race forming about one-fifth of the population of India, that they are active, hardworking, docile, and enduring, and are more sober, self-denying, and less brutish than Europeans. They show greater respect for animal life, and have more natural courtesy of manner. (*Indian Pictures*, p. 52, R.T.S.)

Madura, in Madras Presidency, was an ancient Dravidian capital centuries before the Mohammadan conquest; a kind of metropolis of learning and religion in the far south of India, escaping thus many of the vicissitudes of the war-traversed north.

Rev. W. Urwick, M.A., has written of it thus:—"The ruins of the palace, together with the immense Temple of Siva, covering twenty acres, are standing memorials of its early greatness. Here we come face to face with the master-pieces of Dravidian architecture for which the Madras Presidency is famous, and which, in their number, their vastness, and the elaborateness of their workmanship, astonish and almost bewilder the Christian tourist." (*Indian Pictures*, p. 54.) After describing the Pagoda of Madura, which, he says, dates from the third century B.C., but which was destroyed in A.D. 1324, and restored in the seventeenth century, he briefly refers to the Palace of Tirumala, in Madura, built in 1623, the hall of which is a quadrangle 250 by 150 feet, with an elaborate corridor, and one hundred and twenty-eight massive granite pillars ornamented with stucco, made from *chunam*, or shell-lime.

It is noteworthy that in his description of the above, and also of the still more extensive Dravidian temples of Seringham, which are seven miles in circumference, no mention of decorative tiles or glazed terracotta occurs.

This absence of decorative faience both from Buddhist and Dravidian architecture should be carefully noted.

The most ancient examples of Indian tiles known appear to be those found in the ruins of the city of Gaur, of which there are several specimens

in the Indian Section of the Victoria and Albert Museum, South Kensington, London. Sir George Birdwood, in his *Industrial Arts of India*, tells us not only that Gaur was the old Mohammedan capital of Bengal, but that it was a famous Hindu centre long before the Mohammedan invasion. And he observes that "some of the oldest of the India Museum Gaur tiles are not of any style of Mohammedan glazed tiles known elsewhere in India, and have a marked Hindu character quite distinct from the blue, diapered, and banded tiles which are distinctive of Mohammedan manufacture elsewhere in India before the floral designs of the Mogul period came in vogue." (*Industrial Arts of India*, p. 155.)

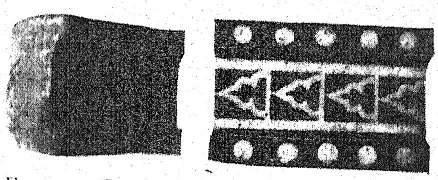


FIG. 72.—Gaur tile or enamelled brick. Indian Section, V. and A. M. (*By permission.*)

He suggests the possibility that these tiles may have had to do with the earlier history of Gaur, and advises an examination of any ruins about the Sena capital of Nuddea for old tiles to compare with those of Gaur.

Mr. Romesh. C. Dutt has kindly written explaining that "Gaur is in Bengal, about one hundred and sixty miles due north from Calcutta. . . . . It was an ancient Hindu capital in the eleventh and twelfth centuries, and when the Mahomedans conquered Bengal they made that place their headquarters for a time. A great plague desolated the city later on, and the people abandoned the place, which has been in ruins since. I should think the glazed tiles and bricks were originally a Hindu art, and the Mahomedans employed Hindu artisans when they began to build their mosques in the old Hindu capital." (*Letter*, 17th May 1903.)

FIG. 73.—Gaur tile or enamelled brick. Indian Section, V. and A. M. (*By permission.*)

A critical comparison of the specimens from Gaur with those from other parts of India impresses us with a sense of their greater antiquity. My son, who, by the kindness of C. Stanley Clarke, Esq., of the Indian Section, Victoria and Albert Museum, South Kensington, has personally examined many of the Gaur tiles, tells me they are, correctly speaking, enamelled bricks or enamelled terracotta rather than tiles; and that he is convinced that if any of the Indian tiles shown in the Indian Section are pre-Mohammadan, these Gaur tiles certainly are they.

The body is similar to that of red bricks, the pieces being moulded on the edges or sides into relief patterns, over which a dark poor blue vitreous dip has

been applied, forming a ground of opaque blue. Upon this ground patterns in opaque white enamel or opaque white clay have been laid. From the dull appearance of the surface, it is uncertain whether the whole was subsequently treated with a glaze or smear, or whether the gloss arises from the vitreous nature of the engobe or enamels. The other parts of the brick or tile surface are merely biscuit red-brick body.

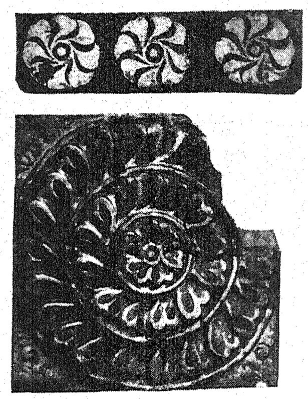


FIG. 74.—Gaur tile or enamelled brick. Indian Section, V. and A. M. (*By permission.*)

By kind permission of the Director we are enabled to illustrate several specimens, but many other forms and patterns than those shown here have been found. "Some of the ornament on pieces in our possession," writes C. Stanley Clarke, Esq., "is distinctly Saracenic, but most of it Hindu without doubt." "The general appearance of this enamelled tilework," says the same authority, "reminds one vaguely of the well-known Florentine Della Robbia ware. . . . . Although the discovery that oxide of tin yields opaque white enamel is credited to Persians, as far back as the thirteenth century, it is quite possible that this secret was also known and utilized by Hindus — or call them what you will — inhabiting Gaur in its early days. Regarding those 'early days,' it is impossible to say whether general opinion, which relegates them to the eleventh and twelfth centuries, is correct."

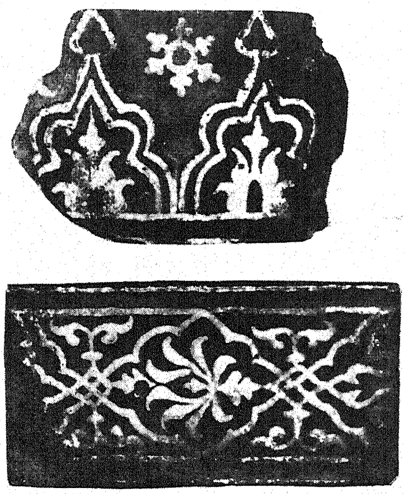


FIG. 75. — Gaur tile or enamelled brick. Indian Section, V. and A. M. (*By permission.*)

Arab influence appears to have been almost inappreciable in Indian art. H. M. Birdwood, Esq., C.S.I., basing his statements upon Sir H. M. Elliot's *Arabs in Sind*, has said :—" The Arab dominion was maintained for three centuries, but left but little impress on the language, arts, architecture, and customs of the people. The Arabs built cities with materials taken from the cities of former rulers ; but their own cities—Mansura, Mahfuza, and Baiza —have entirely disappeared, while the older cities of Bhambora, Alor, Mûltan, and Sehwan still remain." (*Jour. Soc. Arts*, 29th May 1903.)

From A.D. 800 to A.D. 1200 seems to have been a dark age in Northern

India—no great native kings, no notable art or architecture. The tide of war swept over the country again and again, until at length, in the twelfth century, Northern India from Panjab to Bengal was under Mohammadan rule. (*Civilization of India*, p. 79.) The most notorious historical figure of this period was Mahmud of Ghazni, of whom Dutt observes:—"His expeditions served no civilised purpose, did not spread his own faith, and did not conduce to the establishment of a stable empire. They form a sickening record of the plunder of rich temples and towns, the massacre of brave garrisons, and the enslaving of unoffending men and women by the hundred thousand." (*Ibid.*, p. 82.)

Should the ruins of Brahmanabad (Sind)—a vast and ancient city which was suddenly destroyed in A.D. 1020, probably by a sandstorm—ever be thoroughly excavated and examined, further light may be thrown upon early Hindu architecture and products. Fragments of glazed pottery, earthenware, and china are said to have been found there many years ago by Messrs. Bellasis and Richardson, who visited Brahmanabad and partly explored it. (*Jour. Soc. Arts*, 29.4.03, p. 605.)

H. M. Birdwood, Esq., C.S.I., kindly writes that he found some pieces of pottery at Brahmanabad, but they were not coloured like the Hala tiles, and he had no opportunity of making any real search among the sand-covered heaps which constitute all that can be seen of the old town except the walls and one tower (*letter*, 16.9.03). Except for the possible antiquity of the tiles from the ruins of Gaur, then, evidence of any very early use of glazed decorative ceramics in India is for the present apparently wanting Indeed, Sir C. Purdon Clarke, C.I.E., during the discussion upon his paper on "Modern Indian Art," read at the Society of Arts on 15th April 1890, remarked that "if we would leave ancient records alone, and consider only the evidence of existing monuments, we in England could show, date for date, about as good art examples as India, and probably China." (*Jour. Soc. Arts*, 18.4.1890.)

In the course of the lecture he further said:—"The arts of India, in which we are more interested, are, like ourselves, aliens to the country; they belong more to the military splendour of the conquering Mongols than to the pastoral simplicity of Aryan Hindu life. . . . . The period of Roman and Greek history which left such glorious remains in Europe is scarcely represented in India by existing monuments or works of importance. . . . The art-pottery of the country is entirely of foreign origin, and Mr. Mukharji's assumption that glazed pottery is an art introduced from China through Persia is not very far wrong, except when applied to the enamelled architectural pottery of the Panjab, which came in through Persia from Assyria. Of this architectural pottery we know a great deal, as it can be found in a good state of preservation on buildings in Scinde and the Panjab, and we are enabled to compare qualities of this art so far back as the sixteenth century;

but of pottery for domestic use, probably owing to its inferior quality, very little has survived." (*Jour. Soc. Arts*, 18.4.1890.)

As to the circumstances of the manufacture, Sir C. Purdon Clarke, C.I.E., observes that "It is probable that the princes maintained a staff of workmen always engaged in producing for the court. But as several of the Hindu princes use the Persian 'Karkhaneh' or workshop for this portion of their establishment, it may be that this custom was only introduced in imitation of the Moghul court. It was in these royal Karkhanehs that all the great work was done. . . . . In a few places, such as Jeypore, Ulwar, and Vizianagram, royal *Karkhanehs* still exist; but somehow, owing to a mistaken sense of their utility, they could be scarcely said to be producing works of art, except at the Ulwar court, where much decorative work is going on." (*Jour. Soc. Arts*, 18th April 1890, p. 513.)

Sir George Birdwood, K.C.I.E., C.S.I., states that "the old glazed tiles to be seen in India are nearly always from Mohammedan buildings, and they vary in style with the period to which the buildings on which they are found belong, from the plain turquoise-blue tiles of the early Pathan period, A.D. 1193–1254, to the elaborately designed and many-coloured tiles of the latter part of the great Mogul period, A.D. 1556–1750." (*Industrial Arts of India*, p. 155.) In another place the same distinguished authority remarks:—"The art of glazing pottery in Scinde and the Panjab is probably not older than the time of Chingiz Khan. In all the imperial Mogul cities of India where it is practised, especially in Lahore and Delhi, the tradition is that it was introduced from China through Persia by the Mongols, through the influence of Tamerlane's Chinese wife; and it is stated by independent European authorities that the commencement of ornamenting the walls of mosques with coloured tiles in India is contemporary with the Mongol conquest of Persia." (*Jour. Soc. Arts*, 28th February 1879, p. 311.)

According to R. C. Dutt, C.I.E., the great Moghul conquest of India occurred in the following manner:—"Babar, the sixth in descent from the great Tartar conqueror Timur, was born in 1482, and was, after various adventures, expelled from Ferghana and Samarkhand; and seized the kingdom of Kabul in 1504. Twenty-two years after this he . . . . conquered from the Afghans the throne of Delhi." At his death his son Humayun succeeded. This ruler had a chequered career, but his son Akbar became the greatest sovereign India had experienced since the time of Vikramaditya. This Akbar—Akbar the Great, A.D. 1556–1605—was the real builder of the Moghul empire in India.

Influenced by a faith in a supreme God, and enlightened beyond many of his Musulman contemporaries, he treated all sects with tolerance. His capital was Agra; the red sandstone fort he built there was erected after beautiful designs and sculptured by masterly artists. In the province of Gujrat, too, painters and handicraftsmen were numerous, and wonderful

products were made in jewellery and stuffs. The capital of this province—Ahmadabad—was then a very prosperous city with one thousand mosques. (*Civilization of India*, p. 120.)

From 1573 to 1600 A.D. Ahmadabad was considered the greatest city in Western India, and the handsomest town in Hindostan, or perhaps, at that time, in the world. Sir Thomas Rowe is said to have declared it to be "a goodly city as large as London."

This brilliant Moghul period being the most interesting from our present standpoint, a more detailed reference to a few of the principal examples of the use of decoratives tiles in Panjab, Sindh, and Agra will be desirable, to demonstrate the astonishing elaboration of colour and design characterizing Indian architecture at this time.

Two points of historical importance should, however, be borne in mind in the meantime, viz.:—(1) That in 1194 A.D. Kutb-ud-Din conquered Northern India from the Hindus, and thus began the Pathan period.[1] (2) That in 1526 A.D. Babar conquered Northern India from the Pathans or Afghans, and so established a Moghul dynasty in India.

Fergusson, in his *History of Indian and Eastern Architecture*, divides the periods thus:—

Early Pathan style, ...	1193 to 1316 A.D.
Late Pathan style, ...	1316 to 1554 A.D.
Moghul period, ...	1554 to 1706 or 1750 A.D.

With regard to the decorative tilework of these periods, the author is indebted to C. Stanley Clarke, Esq., of the Indian Section, Victoria and Albert Museum, South Kensington, for a very instructive list of existing monuments in India upon which tile-decoration still appears. It reads as follows:—

"*Lahore, Panjab.*—Lahore and district has numerous buildings ornamented with glazed and enamelled tilework and tile-mosaic-work. The following is a selection from some of the most important Muhammadan tombs, mosques, and gateways; Indo-Persian (Mogul period), chiefly seventeenth-century examples. Of these, the Mosque and Tomb of Wazir Khān is easily singled out as the finest.

"1. Tomb of Shah-Mūsa, at Lahore, known locally as 'Sabz Gumbaz' ('the green dome'). Built during the reign of the Emperor Akbar (1556–1605 A.D.). Probably the earliest example, illustrating Persian influence, to be found amongst numerous buildings ornamented with glazed tilework in Lahore and neighbourhood.

"2. Tomb of the Emperor Jahāngir (*d.* 1627) and of his Queen, Nur-

[1] From *Living Races of Mankind*, p. 213, we learn that "By the people of India, Afghans are called Pathans."

Jahān (*d.* 1646), in the Shahdara gardens on the bank of the River Ravi, opposite Lahore. Built about 1620 A.D. It is sometimes claimed that Queen Nur-Jahān erected this tomb in 1630 A.D.

"3. Tomb of Farid Pakkiwala. A religious teacher, pupil of the once important Maj Darya of the court of the Emperor Akbar. Built in the reign of the Emperor Jahāngir in 1621 A.D.

"4. Mosque and Tomb of Wazir Khān, in Lahore. Wazir ('Vizier' or Minister) to the Emperor Shah Jahān. Built 1634 A.D. In excellent preservation, possessing tilework and tile-mosaic-work of extraordinary beauty.

"5. Tomb of Asof Khān (*d.* 1641), at Shahdara, on the bank of the River Ravi, opposite Lahore. Wazir ('Vizier' or Minister) to the Emperor Jahāngir; also a brother of Queen Nur-Jahān. Built about 1635 A.D. (Indian Section, Victoria and Albert Museum, possesses enamelled tiles from this tomb.)

"6. Shahlimar Bāgh, or the Imperial Palace Garden, outside Lahore, has many fine pavilions and gateways ornamented with tilework. Built by Ali Mardān Khān for the Emperor Shah Jahān, in 1637 A.D. (Ali Mardān Khān, an eminent engineer and architect of this period, was in succession Governor of Khandahar, Kashmir, and the Panjab, then minister and director-of-works under Shah Jahān.)

"7. Gateway of the Gulabi Bāgh ('Garden of Roses') at Lahore. All that remains now of this royal garden, built by Sultān Beg, son-in-law of the Emperor Shah Jahān, about 1640 A.D.

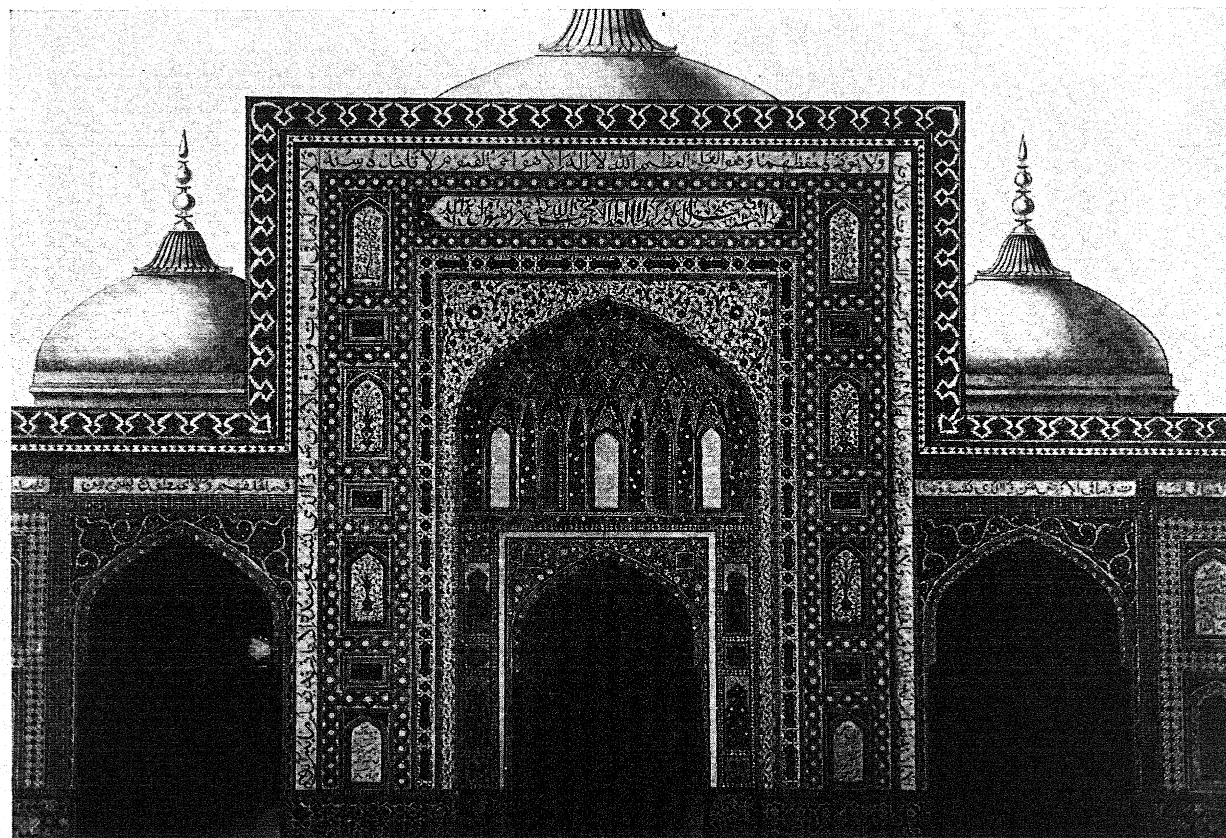
"8. Tomb of Miān Mir, at Mian Mir, near Lahore. A religious teacher of high rank in the reign of the Emperor Shah Jahān. Built by his pupil Prince Dara Shikō, the eldest son of the emperor, in 1640 A.D. (Indian Section, V. and A. M., possesses several enamelled tiles from this tomb.)

"9. Gateway known as the 'Chārburji' ('four towers'). All that remains now of the garden of Zit-un-nissa, daughter of the Emperor Aurangzib. Built about 1665 A.D. (Three towers still adorn this gateway.)

"*Jalandhar district, Panjab.*—1. Jalandhar and district has several tombs of the Lahore type, decorated with similar seventeenth-century tilework and tile-mosaic-work.

"2. Dakhnai Sarai, in the Jalandhar district. A royal country-seat, or one of the Moghul Emperor's numerous halting-places or rest-houses on the road from Delhi through Lahore to Kashmir. Built in Shah Jahān's reign, about 1640 A.D., by the already-mentioned Ali Mardān Khān, minister and director-of-works.

"*Delhi, Panjab.*—1. Indian Section, V. and A. M., possesses some remarkable fragments of early tilework dug up in a garden at old Delhi, consisting of portions of a battlement, cornice pieces, and several tiles; some of the latter have raised inscriptions in Arabic and Cufic characters. Com-



Principal entrance to the Mosque of Wazir Khan, in Lahore. (Built 1634 A.D.)

Photographed from a water-colour drawing by Muhammad Din, a native student of the Lahore School of Art, about 1880. Now in the Victoria and Albert Museum.
(By permission of C. Stanley Clarke, Esq., Indian Section, V. and A. M.)

position, in each case, is red earthenware, with moulded ornament in relief, showing surface remains of turquoise or copper-blue glazing weathered to a green colour in places. Muhammadan work, probably of the thirteenth century.

"2. Numerous Pathán tombs, chiefly of the fifteenth and sixteenth century, are scattered around Delhi, many elaborately ornamented with marble-work, and also decorated with tilework of great beauty both in respect of colour and design. Glazed or enamelled tiles, in copper-blue, cobalt, and mustard-yellow colours, were those most frequently used in external decoration; sometimes, of course, applied as a kind of mosaic-tile-work, the patterns being cut out in one coloured tile, and filled up by a tile of a second colour.

"3. Tomb of Fiezulla Khān (*d.* 1535), known locally as the 'Mālāna Jamāli' (literally 'small palace of beauty'), in the Delhi district, near the ruined city of Taglakābād and the Kut'b Minar. A court poet in the reigns of the Emperors Baber and Humāyun. Built in 1528 A.D. Late Pathán work; externally ornamented with copper-blue, cobalt, and yellow glazed tiles, and the interior with encaustic tiles and coloured plaster-work.

"4. Delhi, and district, has many tombs of the Lahore type, decorated with similar sixteenth and seventeenth century tilework and tile-mosaic-work, mostly without names, and for the most part in ruined condition. (Indian Section, V. and A. M., possesses several fine Indo-Persian tiles from the neighbourhood of Delhi; sixteenth-century work. Composition in each case: red earthenware, enamelled in colours, with conventional floral or foliate patterns on a coloured slip surface, usually of mustard-yellow or apple-green.)

"*Mūltān, Panjab.*—Mūltān has numerous examples of coloured tilework of the Mogul period, but far more characteristic of this neighbourhood is the later 'blue and white' work. Composition: red earthenware, with cobalt and copper-blue decoration, floral and geometrical patterns, on a white slip surface, glazed. Found chiefly on tombs and mosques of the late seventeenth, eighteenth, and early nineteenth century.

"1. Mosque and Tomb of Yusuf Shah Gadez, Muhammadan merchant of Mūltān. Built about 1750 A.D. (Indian Section, V. and A. M., possesses full-sized reproductions, made in Mūltān, of the doorway and other parts of this mosque. A magnificent example of 'blue and white.') [See Chapter III.]

"2. Tomb of a Muhammadan merchant, adjoining the Mosque and Tomb of Yusuf Shah Gadez, at Mūltān. Built about 1750 A.D. (Indian Section, V. and A. M., possesses a full-sized reproduction of the entire tomb, selected as a type or illustration of certain small blue and white tombs in Mūltān.)

"*Agra, N.W. Provinces.*—Agra has tombs and other buildings of the

Lahore type decorated with similar sixteenth and seventeenth century tile-work and tile-mosaic-work.

"1. Tomb of Akbar the Great (Jalál-ud-din Muhammad Akbar, *d.* 1605) at Sikandrá, near Agra. Building commenced by the Emperor himself before 1600 A.D., and completed by his son Jahāngir between 1605 and 1615 A.D. Tile-mosaic-work and tilework is employed for covering the outsides of kiosques round the third floor.

"2. Kanch Mahal (literally 'the palace of glass'), known also as Jodh-Bai's Mahal, on the road leading from Agra to Sikandrá. Built probably by the Emperor Jahāngir as a country residence for Queen Jodh-Bai, about 1610 A.D. The north façade of this building has elaborate tilework after the Lahore type.

"3. The tomb known locally as 'Chini-Ka-Rauza,' on the River Jumna, at Agra; traditionally ascribed to Afzal Khān, the poet (*d.* 1639). Built probably during the reign of the Emperor Aurangzib (1658–1707 A.D.) to the memory of his favorite. The name 'Chini-Ka-Rauza' is derived from the circumstance that the tomb is overlaid with tile-mosaic-work. The glazed patterns are made up of thousands of small pieces of tiles, carefully embedded like true mosaic into the face of the plaster covering the brickwork. On examining the walls it is found that the patterns have been first traced upon the plaster when in a plastic state, and the small tile-mosaic pieces laid accordingly.

"*Tatta, Sind.*—A vast series of Muhammadan tombs are to be found in the vicinity of Tatta, chiefly on the plateau of the Makli range of hills. These extensive ruins reach from Pir Patho, the southernmost limit of the Makli range, to Sammanagar (or Samui), the site of the ancient capital of the Samma rulers of Sind (Samma dynasty: 1351–1521 A.D.), about three miles north-west of Tatta. Kennedy, who wrote of these ruins, described them as a vast cemetery of six square miles, containing, roughly, not less than a million tombs. This tableland, covered with sepulchres of all kinds and sizes, has evidently been used as a sacred burial-ground for many centuries. The most important are those erected under the Mogul dynasty by the princes or governors of the province from about 1570 to 1640 A.D. Great beauty of pattern and exquisite harmony of colouring marks the tilework of this period. The structure is usually of brickwork, ornamented with glazed or enamelled tiles.

"1. Tomb of Mirza Muhammad Baki Tarkhán (*d.* 1585), on the Makli Hills, near Tatta. Prince or Governor of Lower Sind: Tarkhán dynasty. Built about 1580 A.D.

"2. Tomb of Amir Kholil Khān, on the Makli Hills, near Tatta. An officer under Mirza Muhammad Baki Tarkhán, Prince or Governor of Lower Sind: Tarkhán dynasty. Built, between 1572 and 1585 A.D., during the

lifetime of Kholil Khān, but, in accordance with his final wishes, his body was buried near it, and bodies of seven hāfizes (religious devotees) were buried in the tomb.

"3. Tomb of Mirza Jani Beg Tarkhán (*d.* 1599), on the Makli Hills, near Tatta. The last of the Tarkhán governors of Lower Sind: Tarkhán dynasty. Built about 1600 A.D. His son Gazi Beg (*d.* 1611), Governor of the Province of Kandahar under the Mogul Emperors Akbar and Jahāngir, is also buried in this tomb.

"4. Tomb of Diwan Soorf Khān (*d.* about 1644), on the Makli Hills, near Tatta. 'Diwan' or minister to Nawab Amir Khān, a governor of Sind under the Emperor Shah Jahān. Built in 1639 A.D.

"5. Mosque and Tomb of Nawab Amir Khān (*d.* 1650), on the Makli Hills, near Tatta. Governor of Sind under the Mogul Emperor Shah Jahān. Built about 1640 A.D.

"6. The 'Juma Masjid' ('Friday Mosque'), in Tatta. Built between 1644 and 1657 A.D. On this, tilework, with conventional floral ornament in blue and purple on white, has been used. Composition: red earthenware, with decoration in copper-blue, cobalt, and manganese-purple on a white slip surface, glazed. (Indian Section, V. and A. M., possesses reproductions, made in Tatta, of spandrils and other parts of this mosque.)

"*Haidarabad and Hala, Sind.*—In both of these cities, including their environs, are tombs and other buildings decorated with tilework of the Tatta type. The following is selected as an illustration:—

"1. Tomb of Ghulám Shah Kalhora (*d.* 1772), at the northern end of the upper plateau on which the city of Haidarabad now stands. Prince or Governor of Sind: Kalhora dynasty. Built between 1765 and 1768 A.D. This structure, resembling earlier examples, consists entirely of burnt brick with external and internal decoration of glazed tiles. The bricks were made in Haidarabad, and the coloured tiles at Nasarpur, sixteen miles N.E. of Haidarabad. (Nasarpur was once a town of great importance, when the River Indus ran at its base.)

"*Karachi, Sind.*—Karachi has several tombs of the Tatta type.

"1. Tomb of Yār Muhammad Kalhora (*d.* 1719), near Burdani, in the Karachi district. Prince or Governor of Sind: Kalhora dynasty; sometimes known as 'Khuda Yār Khān,' the title bestowed on him by the Mogul Emperor Aurangzib. Built about 1715 A.D.

"*Concluding note.*—An interesting form of mural decoration, sometimes used in India, is the composite of 'marble-inlaid-work' and 'tile-mosaic-work.' Persian craftsmen were probably the first to execute architectural patterns in this intermixture of various coloured marbles and glazed or enamelled tiles. The results yielded are remarkably pleasing. (The Persian Pottery Court, V. and A. M., possesses several fine slabs of this material, taken from the Great

Muhammadan College, at Ispahan, the 'Madrasa Mādari Shah Sultan Hussain' (viz., 'The College of the Mother of Shah Sultan Hussain), built in 1710 A.D." (Signed) C. STANLEY CLARKE."

When we reflect that nearly the whole of these numerous and beautiful examples of decorative tilework were completed two centuries before Minton had even thought of making tiles, we feel disposed to assent to the dictum of the Earl of Kimberley; Secretary of State for India in 1885, who said, respecting India, "We have much more to learn from than to teach them."

With special reference to Sind, H. M. Birdwood, Esq., C.S.I., M.A., kindly writes:—"The three places where old tiles are to be seen on buildings or tombs in greatest profusion are:—

"1. Tatta, in Karachi Collectorate, where the principal mosques are simply glorious with colour and reflected light on the inner walls, the prevailing tone being a deep rich blue.

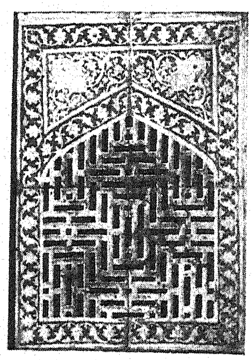


FIG. 76.—Sind lattice window, 3 ft. by 2 ft. 2 ins. Glazed tilework, cobalt and copper blues on white slip over red earthenware, four sections. Made in Hala, Sind, eighteenth century. India Section, V. and A. M. (*By permission.*)

"2. Sehwan, on the Indus, where the tombs of many saints are decorated with tiles.

"3. Hyderabad, where the tombs of the Kalhara kings are similarly decorated.

"Tiles are mostly manufactured now, and I believe have always been manufactured, at Hala in the Hyderabad Collectorate."

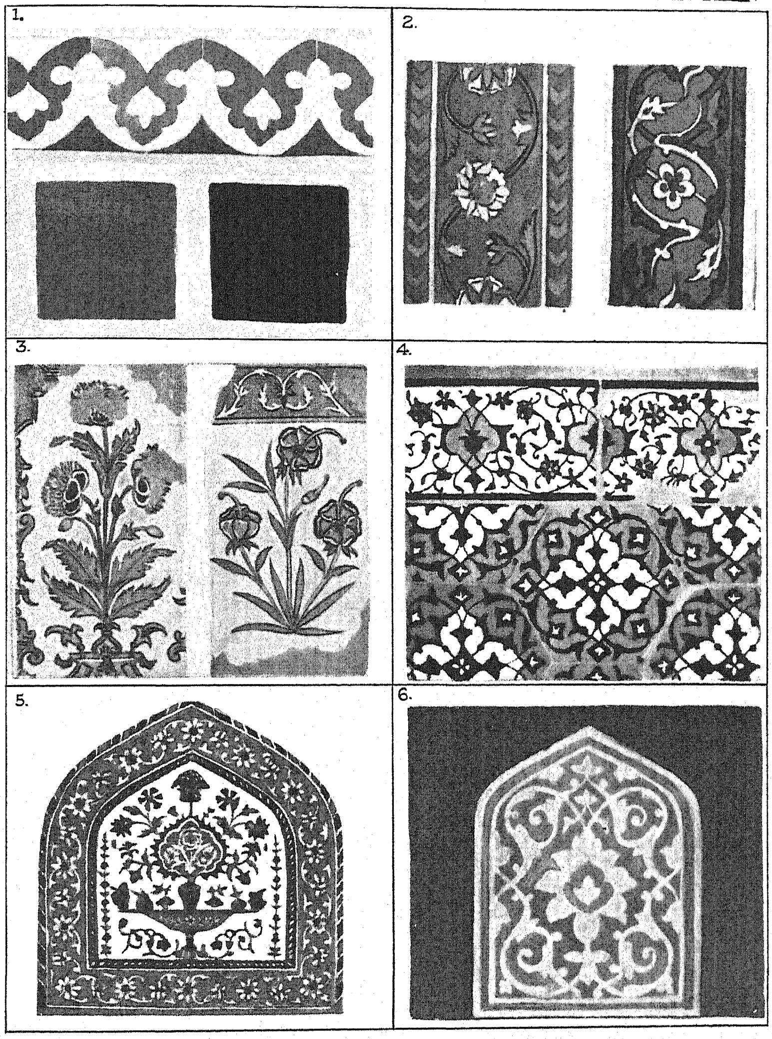
From Sir George Birdwood's *Industrial Arts of India* we learn that the chief centres of glazed pottery manufacture in Sindh are Hala, Hyderabad, Tatta, and Jerruck; and the chief places for the manufacture of encaustic tiles in Sindh are Bulri and Saidpur. He mentions tiles, pinnacles for the tops of domes, pierced windows, and other architectural accessories, glazed more or less in turquoise of the most perfect transparency, or in a rich dark purple, dark green, or golden brown, sometimes diapered all over by the *pâte-sur-pâte* method.

Mr. Drury Fortnum, in his report on the pottery of Sindh shown in the International Exhibition of 1871, observed:—"The turquoise blue painted on a paste beneath a glaze, which might have been unearthed in Egypt or Phœnicia . . . . is of the same blood and bone as the ancient ware of Thebes . . . but the tiles are very important—they are in general character similar to, although not so carefully made as, the Oriental tiles known as Persian, which adorn the old mosques of Egypt, Syria, Turkey, and Persia. . . . . The colours used upon them are rich copper green or golden brown and dark and turquoise blue." (*Industrial Arts of India*, p. 140.) Sind appears to be

DETAIL-TYPES OF INDIAN DECORATIVE TILEWORK.

Selected by C. Stanley Clarke, Esq. Indian Section. Victoria and Albert Museum.

PL. XIII.



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1. Tile mosaic border from old Delhi. Late Pathan type. 15th century.
2. Tile boarders from Tombs at Delhi. Mogul type. 16th century.
3. Tiles from tombs of Asof Khân at Lahore. Mogul type. 17th century.
4. Tilework from a tomb on the Makli plateau. Sind. Tatta type. 17th century.
5. Detail from a tomb in Multan. Multan " blue and white " type. 18th century.
6. Detail from a tilework frieze. Sind. Hala type. 19th century.

specially remarkable for embossed tiles and faience of red body, slip painted with white, and then the whole glazed with a dark green glaze.

Respecting these, C. Stanley Clarke, Esq., kindly writes as follows :—" The ordinary coloured glazes of Tatta and Hala, in Sind, are :—

" 1. Turquoise	Siliceous (leadless) glazes coloured with oxides of	Copper.
" 2. Cobalt blue		Manganese.
" 3. Purple		Cobalt.
" 4. Amber yellow	Lead glazes coloured with oxides of	Lead.
" 5. Green		Lead + copper.
" 6. Chocolate brown		Lead + manganese.

" Both towns still produce a moderate quantity of coloured-glazed, slip-decorated pottery and tilework, not only in green (No. 5), as remarked by Sir George Birdwood, but also in the clear amber yellow (No. 4)."

Referring again to Panjab (*i.e.*, five rivers), the district around the five great tributaries of the Indus, annexed by the British A.D. 1849, to which also the district around Delhi was added subsequently, here during the sixteenth and seventeenth centuries the art of glazing and of ceramic decoration attained a high level of excellence.

Mûltan, or Mooltan (captured by the British A.D. 1849), had been a historic city from the time of Alexander the Great; and even long before that the Greeks are said to have travelled to Northern India in search of knowledge, and the country was, at that early period, populous, well-cultivated, and yielded valuable productions of nature and art. (*Jour. Soc. Arts*, 29.4.03, and Cassell's *History of India*, p. 3.)

Lahore, situated two hundred miles N.E. of Mooltan, was a great city a thousand years ago ; it is much less now, and the great mosque there is said to be deserted. But, as already shown, its former splendour, now departed, has left many vouchers in the magnificence of the tilework and other architectural remains on its ruined monuments. Amritsar, near Lahore, where we approach the " savage desolation and appalling sublimity of the Himalayas," still also cherishes a gem of Sikh-Muhammadan art in its " Golden Temple," to which further reference will be made in another chapter, because of its beautiful mosaics.

At Delhi, " the Rome of Asia for three thousand years "—on the River Jumna, one thousand miles from Calcutta—there is the great Friday Mosque (Juma Masjid), built of red sandstone and white marble, having three graceful marble domes, with spires of copper, gilt. The mosque is said to be paved with nine hundred immense slabs of marble; but neither in this building, nor yet in the equally wonderful Kut'b Minar, near by, can we learn of any glazed tilework.

The decorative tilework of the North-West Provinces is perhaps most effectively illustrated and explained in the late Edmund W. Smith's *Moghul*

Colour Decoration of Agra, constituting vol. xxx. of *The Archæological Survey of India* (Kegan Paul, Trench, Trübner, & Co.), several of the illustrations in which we are graciously permitted, by the Government of the United Provinces of Agra and Oudh, and with the consent of J. H. Marshall, Esq., Director-General of Archæology of India, to reprint in this volume. Mr. Edmund W. Smith writes as follows:—

"The Moghul style of architecture, which sprang up about the year A.D. 1556, under Akbar the Great, terminated about the year A.D. 1658. . . . . Majestic edifices erected by Akbar, Jahângîr, and Shâh Jahân . . . . to this day excite the admiration of the world. Between Akbar's buildings and those of his son Jahângîr there is, as a rule, but slight difference . . . . but between their buildings and those of Shâh Jahân there is a most marked and decided difference, which even the uninitiated cannot but observe. Akbar's and Jahângîr's works are strongly infused with Hindu architecture. Timber is almost unused, and the arch sparingly so; but under Shâh Jahân the Hindû element becomes less and less prominent, until it gradually fades away. The Hindû bracket and flat architrave used over the aperture of doorways and windows makes way for the Muhammadan arch, and the beautiful carved geometrical decoration in red sandstone, as found at Fathpûr Sîkrî, and the Jahângîr Mahâl in the fort at Âgrâ, gives place to mosaic in *pietra-dura*, as exemplified in Îtimâd-ad-daula's tomb and the Tâj. . . . .

"Besides marble mosaic and *pietra-dura* inlaid ornamentation, the Moghuls relied to some extent, as did the Pathâns before them, on enamelled tiling for the enrichment of their buildings. It had been employed from an early period by the Persians upon their structures, and came into use in India about Sher Shâh's time. Akbar used encaustic tiling upon the stately palaces at Fathpûr Sîkrî for roofing purposes, and for enriching architraves and borders round doorways, etc.; and Jahângîr also used it for covering the domed kiosks round the third story of his father's mausoleum at Sikandra, and in the Kâñch Mahâl. In these and other buildings it was sparingly used, but in the mosque erected at Lahor by Jahângîr's vizir, and the Chînî-Kâ-Rauza, Âgrâ, built, it is supposed, in Aurangzîb's reign, we find the walls, as in many Persian buildings, covered throughout with encaustic tiling. This style of decoration is called Kashâni, after Kâshân in Persia, one of the chief seats of earthenware manufacture. . . . .

"Few Moghul buildings appear to have been entirely covered with enamelled tiling, and about the only one in Northern India is the Chînî-Ka-Rauza at Âgrâ. . . . . The difficulties connected with the manufacture of enamelled tiles probably accounts for their being so sparingly used. Red sandstone was easily procurable, and could be obtained in any quantity from quarries just outside Fathpûr Sîkrî, whilst marble could be imported from the neighbourhood of Jaypur. The manufacture of glazed tiles was no

Pl. XIV.

AGRA. CHÎNÎ-KA-RAUZA.

Tiled Panel, East Façade. Reproduced from Pl. XVII, of "*Moghul Colour Decoration of Agra.*"

(By Permission of the Government of the United Provinces.)

doubt introduced into India from Persia; it was not indigenous to the country, and the art has almost died out. . . . .

"The Chînî-Kâ-Rauza (fig. 77), or the tomb covered with 'china' (enamelled tiles), stands in what was a large garden, but is now a field. . . . . Being a mausoleum, it is built facing north and south, as all such in India are. At the north-west corner of the enclosure, commanding a fine view of the river, is a picturesque tower crowned by a cupola, which, like the kiosks round Akbar's tomb at Sikandra, was originally coated on the outside with enamelled tiles. . . . . There is nothing striking about the design of the façades to call for special comment. . . . . The faces of the abutments upon the sides of the arches . . . . are enriched with quotations from the Qu'rân in Arabic, in Tughrah characters. The characters are in blue upon a ground of white tiles, enclosed by narrow floral borders in blue, yellow, and green tiling. On the outer sides the abutments are bordered by slender perpendicular shafts which extend from the ground to some distance above the roof. They are covered with crimson, orange, and white tiles laid in a zigzag pattern. . . . . At the four angles of the building are similar shafts or guldistas, and these are veneered with tiles in royal blue interspersed with narrow trefoil-shaped bands running in parallel rows horizontally across the shaft. Although so simple, the effect is pleasing, and far more so than much of the tiled ornamentation upon other parts of the mausoleum.

". . . . But to revert again to the large archways in front of the vestibules in the centre of the façades. The spandrils above the arches were overlaid with glazed tiling wrought into rich and beautiful scrolls, mainly in blue upon an orange ground. . . . . Generally speaking, one façade is like the other in design, but the tiled patterns with which they are covered vary considerably. . . . .

"Exteriorly the tomb is covered from top to bottom with mosaic, in tiling in a variety of colours, worked up into numerous patterns, so as to form one unbroken flat surface. The interior is floated with stucco, painted with rich and bright floral designs. . . . .

"The crypt, it is to be deplored, has been used for years as a cattle-shed . . . . and the result is that very little vestige is left of the dadoes, which were of coloured tiling.

"The glazed patterns are made up of thousands of small pieces of tiles carefully embedded like mosaic into the face of the plaster covering the brickwork. Where portions of the tiling have fallen, the original position of each separate piece of tiling as it was embedded into the plaster can be distinctly traced. . . . . The joints between the different pieces of tiles are distinctly traceable, and are not mere shallow lines of demarcation between the coloured patterns, as has been asserted by a former explorer. . . . . One cannot say definitely of what substance the tiles are composed, but it is

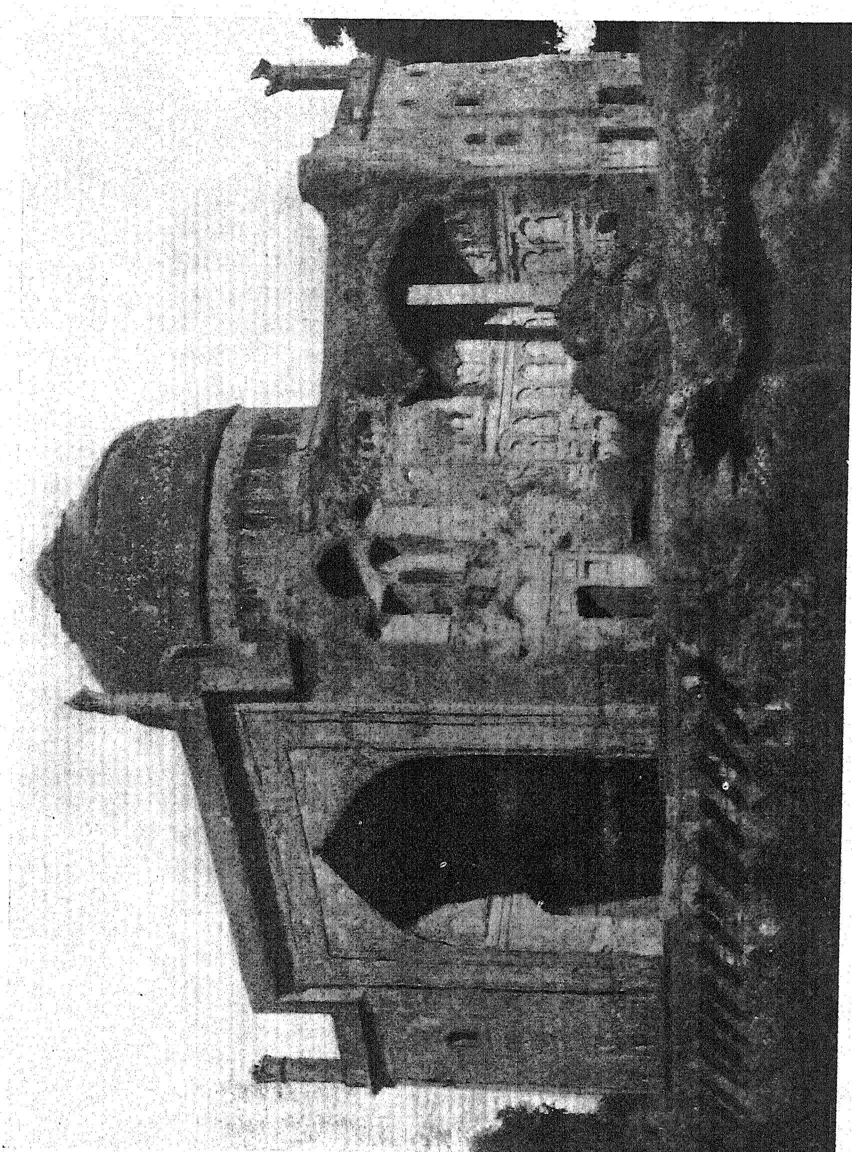
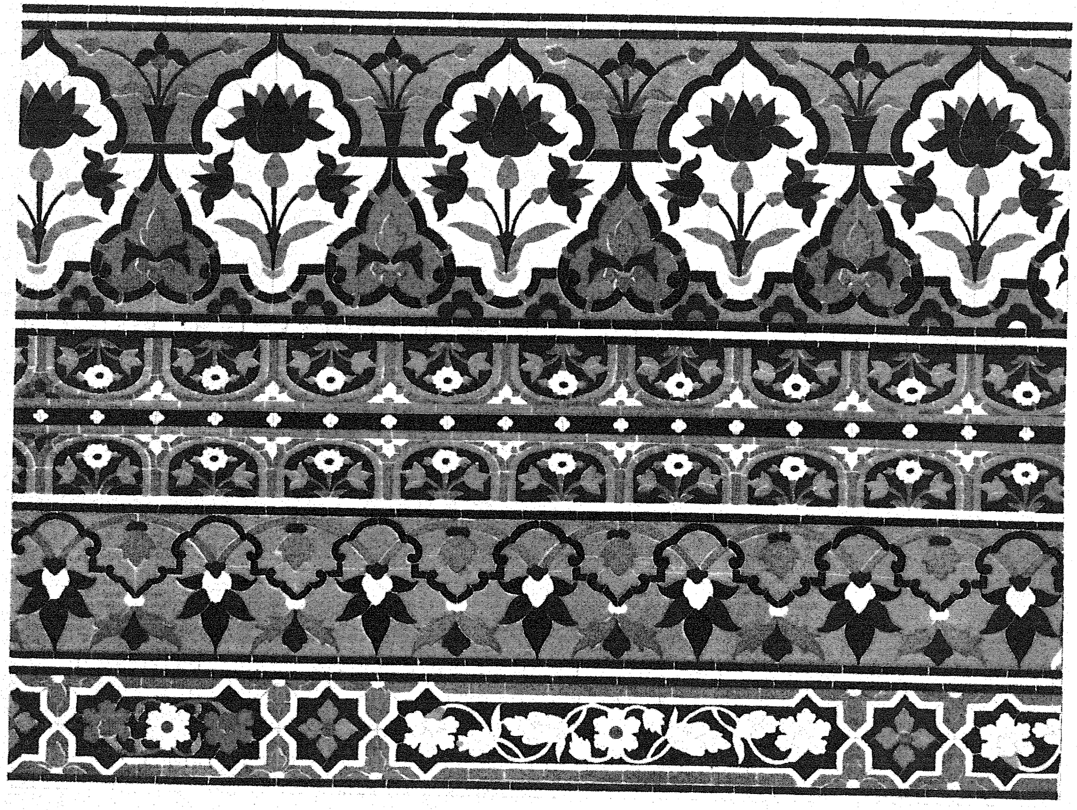


FIG. 77.—Chīnī-Kā-Ranza. (*Reprinted from "Moghul Colour Decoration of Agra." By permission of the Government of the United Provinces.*)



AGRA. CHÎNÎ-KA-RAUZA.

Detail of Tiled Parapet and Cornice round top of the building. Reproduced from Edmund W. Smith's "*Moghul Colour Decoration of Agra.*" Pl. XIX.

(By permission of the Government of the United Provinces of Agra and Oudh.)

evident they are caustic, or tiles which have been subjected to an almost incandescent heat. The glazed surface is only the thickness of the blade of a knife. They have certainly been subjected to heat, and are not 'merely made of mortar or cement enamelled over,' as has been asserted by some people. . . . .

"The principal colours employed are blues, greens, oranges, vermilions, lakes, etc. . . . . It is impossible to describe the full effect of the tiling; there is that about it which baffles description, and to be fully appreciated it must be seen. . . . ."

Referring to one particular detail, the pattern of a lattice, Mr. Edmund W. Smith writes:—"Similar designs are met with in Chinese work, and it is not impossible that some of the workmen employed on the decoration of the Chînî-Kâ-Rauza came from China or Japan, or more probably the designs travelled from China into Persia, and from thence to India." In conclusion, Mr. Smith says:—"It is impossible to say by whom the chamber was decorated. It is evident the artists were of no mean order, and although most of the decoration may have been done by Indian artists, it is not improbable, judging from various indications, that Chinese decorators assisted in the work. It is deeply to be regretted that more care was not taken in years past to preserve the mausoleum, which is certainly one of the most interesting in Northern India. Time has, no doubt, had much to do with the present condition of the building, but what time has not done, man has. The tiling on the exterior has been wantonly hacked off by visitors without taste, wishing to carry away to distant homes souvenirs of the place.

"For whom the tomb was built we do not know. It bears no inscription, but is traditionally ascribed to 'Afzal Khân, a poet, who died at Lahôr in A.D. 1639. In all likelihood it was built during 'Aurangzîb's time."

In chapter iii. of the same work Mr. Smith writes:—"Similar tiling to that used for decorating the exterior of the Chînî-Kâ-rauza was . . . . employed for covering the outside of the kiosques round the third floor of Akbar's tomb at Sikandra, commenced by Akbar himself, but completed by his son Jahângîr between A.D. 1605–1615. The illustration (plate xvi.) represents the cupola of one of the kiosques, showing the manner in which the tiles are laid, and the remaining plates show the designs in detail. In most cases star patterns, surrounded or combined with hexagonal or other geometrical figures, have been used. In some places portions of these patterns have fallen, and have been replaced by tiles of a different design." (*Moghul Colour Decn.*)

In chapter iv. Mr. Smith describes the KÂÑCH MAHAL at Sikandrâ. He says:—"A little way to the east of the main entrance to Akbar's tomb at Sikandrâ, within a walled garden, presented some thirty years ago by Government to the Church Missionary Society, is a very fine specimen of early seventeenth-century domestic architecture. The house was probably built by

the Emperor Jahângîr for his Queen Jodh Bai, as it is sometimes called Jodh Bâî's Mahal. . . . . The residence stands on the right-hand side of the main road leading from Âgrâ to Sikandrâ, but as it is hidden among the trees of the garden it can hardly be seen by passers-by. . . . . The top of the window is roofed by a half-dome in cement, covered on the exterior with parallel rows of star-shaped encaustic tiles in blue and green, embedded in hexagonal borders of an orange colour. At the springing of the roof is a battlemented *fascia* in red sandstone, inlaid with orange and blue tiles. The general effect of the tiling, combined with the dark red sandstone traceried windows, is most effective.

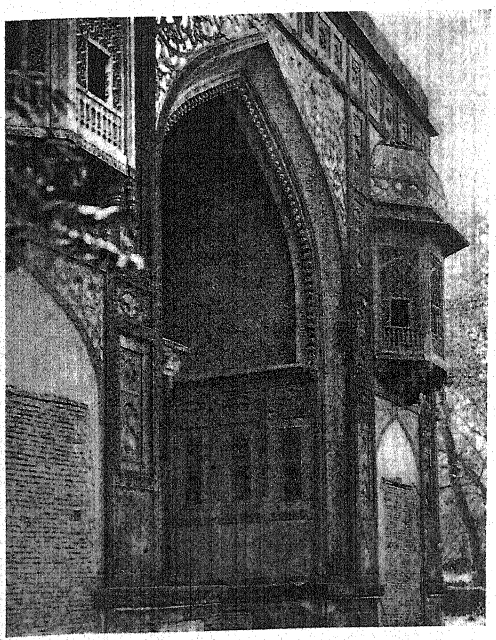


FIG. 78.—Kâñch Mahal gateway.

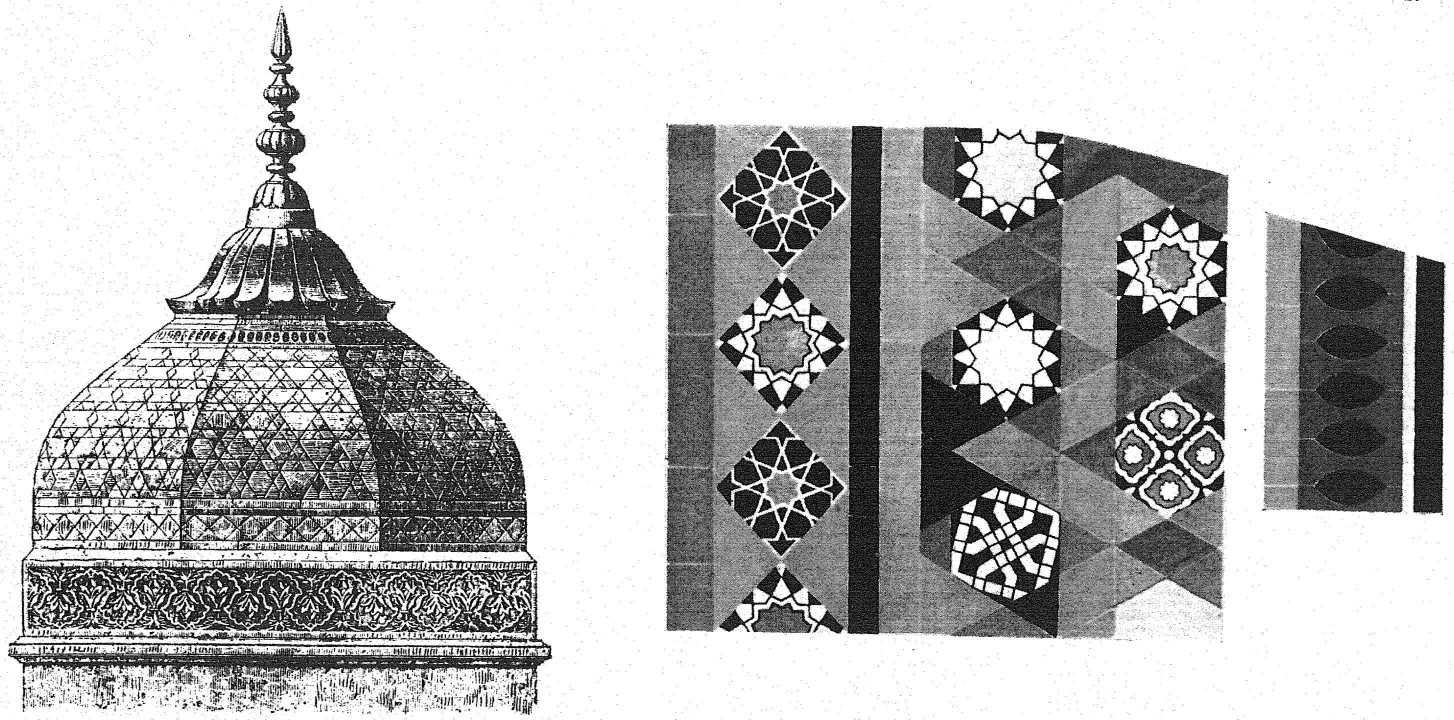
"Extending all along the top of the façade is a series of panels. . . . . Above the panels is a string moulding inlaid with green enamelled tiling, and over it a red sandstone parapet. . . . . The *merlons* are engrailed and inlaid with blue and the *embrasures* with orange-coloured tiles.

"The spandrils above the arch are enriched with raised floral scrolls in red sandstone, the interstices between the scrolls being veneered with white marble. . . . . In earlier Moghul work . . . . we find the spandrils almost plain, a boss only being carved in the centre. Flowing tracery was not in general use . . . . till the seventeenth century.

"It is seldom one sees a house so profusely and elaborately carved as the Kâñch Mahal, and yet not in bad taste. The Turkish Sultâna's and Bir Bal's houses at Fathpûr Sîkrî, erected during the latter part of the sixteenth century, are considered to be among the most minareted carved buildings in India, but the north façade of the Kâñch Mahal vies with even if it does not excel them." (*Moghul Colour Decoration of Agra*, p. 26, Kegan Paul, Trench, Trübner, & Co.)

Respecting the nature and mode of manufacture of this Moghul Indian tilework, Mr. Smith expresses the opinion that, as most of the colours used in the manufacture of the Sind and Panjâb tiles are found upon the walls of the Chînî-Kâ-rauza, and as far as one can judge the enamelling was prepared in the same way, the manufacture of Indian encaustic tiles and pottery, as

Pl. XVI.



SIKANDRÂ. AKBAR'S TOMB.

Tiled ornamentation upon the Kiosques round the Third Floor. Reproduced from Pl. LIX. of "*Moghul Colour Decoration of Agra.*"

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described by Sir George Birdwood, K.C I.E., in his *Industrial Arts of India*, may be looked upon as furnishing a probable explanation. This information will be mostly found in the *Journal of the Society of Arts*, 28th February 1879, where the recipes for the glazes are minutely described.

With regard to Burma, Taw Sein-Ko, in his monograph on the pottery and glassware of Burma, mentions that, long before ceramic art achieved any public recognition in Europe, the pottery of Burma had become famous. He tells of huge jars—*Martabans*—mentioned by an Arabian traveller in the fourteenth century. These things and other beautiful products in porcelain and glazed earthenware were highly prized among the Moors who traded with the Far East. But the things that appear to possess most interest from an antiquarian point of view are peculiar glazed terracotta tablets, modelled in very high relief, and enamelled or glazed with bright green and red enamels, and some opaque white. Taw Sein-Ko tells us they are found mostly at Tagaung, Pagan, Prome, and Pegu, the ancient capitals of Burma. Specimens are to be seen in the Phayre Museum, Rangoon, and in the Indian Section, Victoria and Albert Museum, London. The designs partake rather of the grotesque than the decorative, and probably had some religious or allegorical signification.

Chinese.—It is customary to attribute great historical antiquity and continuity to the Chinese. Rev. John Ross asserts that the Chinese attained a high degree of civilization at a period when every other existing nationality was still in the grossest barbarism, and from earliest recorded times they were surrounded by people who were their mental and social inferiors. (*Sunday at Home*, 1889, p. 87.)

On the other hand, E. H. Parker, Esq., Reader of Chinese in the University of Liverpool, who was for many years resident in China, has kindly written to me, saying:—"As to the records question, I see no reason to disbelieve Chinese traditions, but there is nothing of value in them, even if true; no dates, no financial, social, or other definite facts. Most of the literature was destroyed in B.C. 213, and what has been recovered is all barren 'philosophy'—no science or 'sound stuff' of any kind, at least older than B.C. 700." (See also p. 16 of *China: her History, etc.*, Murray.)

When the average Briton essays to study the history of China, he finds that it is not so much a single country as a vast continent teeming with populations of more or less mixed origin, much as other continents are; and that, so far from China having had one long-continued peaceful and perfectly secluded growth, it has been the battle-ground of Manchu, Mongol, Kitan, Tartar, and Turk; and its coasts have been the scene of intense activity and commerce by Hindu and Arab, long before Vasco de Gama doubled the Cape of Good Hope (A.D. 1497) with his Portuguese ships, to be soon followed by Dutch, French, and British. China, like other continents, has been ruffled again and again by the passage of troops, has suffered many changes of dynasty, and

for half its historical period has been divided nationally north from south. (See *China: her History, Diplomacy, and Commerce*, pp. 25, 26, 30, 182–188, Murray.)

We must therefore leave ancient traditions alone, and seek our facts about Chinese faience in the existing or only recently destroyed examples. Much has been written in European about Chinese porcelain, and something about their stonewares, but very little, apparently, about their decorative faience, or whatever the material really is of which their coloured glazed tiles are composed.

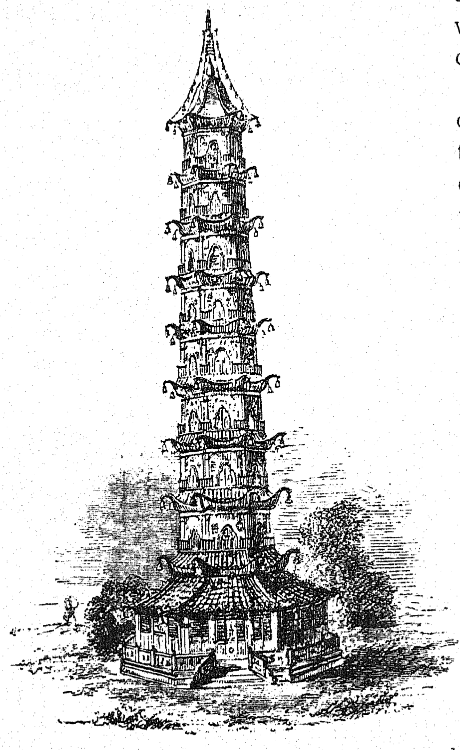


FIG. 79.—Porcelain Tower of Nanking (destroyed 1853). (*From Marryat's "History of Pottery and Porcelain." By permission of Mr. John Murray.*)

Marryat certainly mentions the once famous tower of Nanking, and tells of several eccentricities of the emperors of China. It seems that they had a special weakness for commanding the manufacture of articles of an almost impracticable nature, under threats of severe penalties. Marryat tells of one who ordered plaques or tablets to be made for a porch, each tablet to be the equivalent of 3 feet high, $2\frac{1}{2}$ feet broad, and $\frac{1}{2}$ foot thick. After many attempts it was found they could not be made, and the mandarins petitioned the emperor that the work be discontinued. Still certain plaques were made, and used for overlaying the walls of palaces and temples, their brilliant glaze and varied colours giving an air of magnificence. (*History of Pottery and Porcelain*, p. 224, Murray.)

In a particularly interesting and instructive paper on Peking, read before the Society of Arts by Thomas Child on 30th January 1895, expressing the results of an experience of twenty years' residence in China, he refers to the wonderful Peking Observatory—"the oldest in the world, and perhaps the most dilapidated." It was erected in 1275 A.D. by the Mongol Emperor Kublai Khan. On the north side there are, it seems, some buildings covered with yellow porcelain (?) tiles, with which also all the palace buildings are roofed. Notwithstanding the fierceness of the winds during the winter, he tells us there

are no fireplaces, as we understand them, in Chinese houses; they protect themselves by wadded clothing and only use fire for cooking purposes. This, then, easily accounts for the absence of anything like stove tiles or faience fireplaces in China.

Mr. Child also mentions a magnificent porcelain (?) arch, covered with yellow tiles, in the Hall of Classics near the Confucian temple; and if we understand him correctly, the wall of the inner, *Imperial*, city, which extends for seven miles, is roofed on the top throughout its whole length with yellow porcelain tiles, and Mr. Child remarks that "This is a characteristic of Peking. All the public buildings are covered with these glazed tiles, every dynasty having its own colour, some green, some yellow. The present dynasty, which is the 'Ch'ing' or 'pure,' has adopted yellow. All the palace buildings are covered with tiles of this colour." (*Jour. Soc. Arts*, February 1895, p. 217.)

Speculations upon the possibility of the art of enamelling having been communicated, one way or the other, between China and Babylonia and Egypt at a remote period, or between Persia and China in more recent times, will not serve any very useful purpose here; even the date of the invention of porcelain, probably a much more recent matter, is placed at very different periods by those who have attempted to fix it. Thus, in the *Handbook to the British Pottery and Porcelain in the Museum of Practical Geology, London*, 1893, we read :—"It is certain that porcelain was manufactured in China at a very early date. According to the researches of M. Stanilas Julien, the manufacture was commenced . . . . at some time between B.C. 185 and A.D. 87. Dr. Hirth, however, believes that the use of Kaolin was not introduced until some time after A.D. 536 . . . . while M. du Sartel also refers the origin of porcelain to . . . . 618 to 906. According to Mr. Hippisley, 'No specimens manufactured prior to the advent of the Sung dynasty have survived to the present day': this dynasty extended from 960 to 1259. Mr. Franks remarks that 'it was under the great native dynasty of the Mings (1368 to 1644) that the manufacture of porcelain received its greatest development.'" (*Handbk. M. P. Geol.*, 1893, p. 10.)

Early in the sixteenth century there must have been many ceramists of considerable ability in Korea, for the late Mr. Ernest Hart, in his paper on "Japanese Pottery and Porcelain," read before the Society of Arts in February 1892, describes how an expert from Korea was taken over to Japan to search for natural materials for the manufacture. And several instances are related of Japanese chieftains having crossed over the seas to raid Korea for loot and for artisan captives, among whom were potters, who greatly assisted in originating whatever of pottery and porcelain there is now in Japan.

But the foregoing is "by the way"; for after much rather fruitless searching for accurate information about Chinese decorative wares, the author at last ventured to appeal to that prince of writers on Oriental ceramics, Dr. Stephen

W. Bushell, C.M.G., M.D., who for over thirty years was the distinguished resident physician to the British Embassy at Peking. The appeal was met with utmost courtesy, promptness, and candour. The learned doctor most willingly furnished an essay on the subject, which is appended in full, and which we believe to be unique so far as this particular feature of Chinese art and architecture is concerned.

"NOTES ON THE DECORATIVE AND ARCHITECTURAL USE OF "GLAZED TILES AND FAÏENCE IN CHINA.

"By Dr. STEPHEN W. BUSHELL, C.M.G., M.D.

"The Chinese employ glazed pottery very extensively for the facing of buildings, for roof-tiles, and as architectural ornaments. The framework of the skeleton of their palaces, temples, and other large buildings being always constructed of wood, and supported upon strong cylindrical wooden pillars, the outline is generally filled in with bricks, supplemented usually by moulded panels of terracotta. The bricks and moulded panels used in the construction and external facing of the walls are occasionally covered with coloured glazes, while the tiles which cover the roof, the most prominent and characteristic feature in Chinese architecture, are always glazed in bright colours, so as to distinguish the palaces of the emperor, the residence of a prince of the blood, or one of the many State temples. Glaze is called *liu-li* in Chinese. The exact period of its introduction is unknown, but it was certainly in use during the Han dynasty, which flourished from B.C. 202 to A.D. 220. The centre of fabrication of coloured glazes in the present day is *Po-shan-hien*, in the province of Shantung, where some three-fourths of the population are engaged in the manufacture. The whole region outside the city walls is said, in a recent account (*North China Herald*, 27th January 1903), to be dotted with kilns, where coloured glass of fair quality is made from materials produced in the vicinity, the place being renowned for the finish of its glasswares and for its articles of imitation jade, glazed tiles, etc. In addition to these things, rods of coloured glass, about thirty inches long, are moulded here, and tied in bundles for exportation to other localities, to be used there for the decoration of porcelain and faïence in enamel colours, and for the fabrication of painted and *cloisonné* enamels in copper, as well as for coating tiles and bricks of architectural faïence. These last are made locally wherever suitable deposits of fine clay occur. There is an imperial manufactory near Peking, in the Western Hills, about twenty-five miles from the city. The principal glazes used in these kilns, previously prepared with a lead flux, are a deep yellow from antimony and iron peroxide, a dark green from copper persilicate, and a purplish blue from the native cobaltiferous manganese mineral. Among other colours less frequently used are a beautiful turquoise blue composed of

copper with nitre flux, and a brilliant ruby red which owes its tint to the same protean metal. White porcelain is occasionally used in architectural decoration as an effective contrast to panels of coloured faïence. We owe the earliest record of the famous kilns of Chingtechen in the historical annals to the entry that in the year 583 A.D. the last emperor of the short-lived Ch'en dynasty ordered a supply of porcelain plinths to be made there for the palaces he was building at Chien-K'ang (now Nanking). The celebrated porcelain tower which was built in this city on the site of an older pagoda in the reign of the Emperor Yung-lo (A.D. 1404–24), and formed a conspicuous ornament of the ancient capital till it was destroyed by the Taiping rebels in 1853, was cased with L-shaped bricks of white porcelain, coated with a lustrous white glaze, together with faïence bricks moulded with Buddhist emblems and enamelled in colours. A scroll-picture of this pagoda, which was 260 feet high, with eight sides and nine stories, is in the British Museum, as well as actual specimens of the bricks, panels, and antefixal ornaments from the roof. One of the descriptions may be quoted here from the catalogue by Sir Wollaston Franks:—'*Architectural Panel.*— Chinese pottery, moulded in relief, and glazed with white, red, green, and yellow; on it a yellow throne, on which are three bud-like objects, one white, another red, and the third green, symbolizing the San-tih, or three moral excellences of Buddha; behind are wavy rays of the four colours mentioned. From the Porcelain Tower at Nanking, commenced by the Emperor Yung-lo, and terminated in 1430; destroyed 1853. Height 13 inches, width 6 inches. 921.'

"The Emperor Hsuan-te was reigning in 1430, when the porcelain of the period was remarkable for the brilliancy of a ruby-red monochrome glaze produced from copper, the identical colour which distinguishes some of the rays of the halo on this panel, and makes it of special interest to the student of Oriental ceramic art.

"There are several porcelain or rather glazed faïence pagodas of the same kind, but of less imposing proportions, in the grounds of the summer palaces near Peking, which were built in the reign of the Emperor Chien-lung. The temple of the same period, at the top of the Wan-Shon Hill (in the photograph) [fig. 80], is built of large bricks, each one of which is moulded with a niche in which a figure of Buddha is enshrined, picked out with green on a yellow background; the roof-tiles are glazed in the same two colours, as well as the three dagabas and the dragons on the crest of the roof, and the grotesque antifixal animals on the eaves.

"The picture (photo No. 2) of the three-arched gateway [Plate XVII.] or Pai-lou, at the entrance of the Buddhist temple, Wo Fo Ssŭ, will give a general idea of the decorative effect of enamelled faïence. The foundation and arches, built of carved slabs of white marble, support a framework of wood which is entirely overlaid with plaques of faience, moulded with varied ornamental

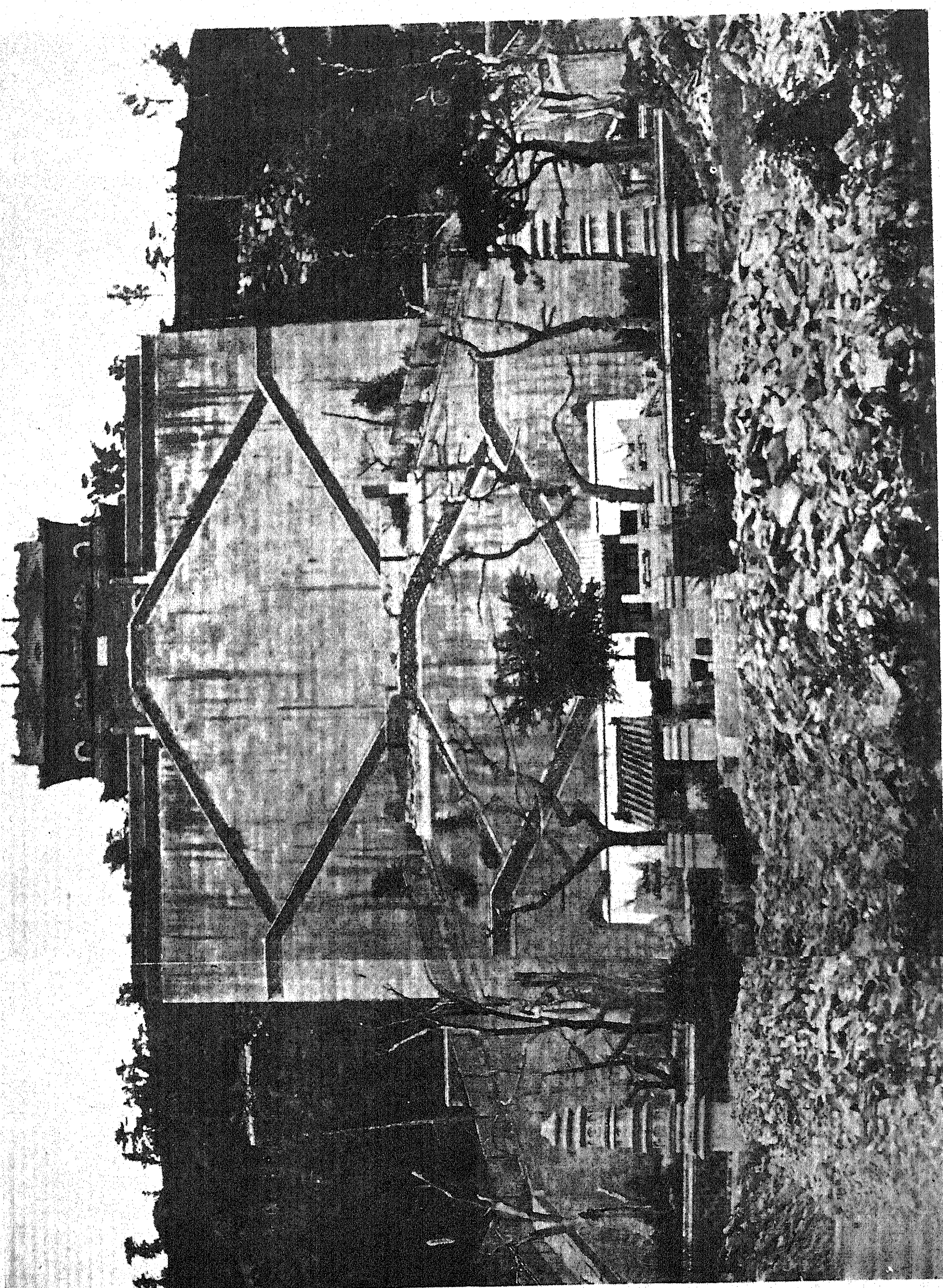


Fig. 80.—View of the ruins of Wan-Shon Shan (since restored), taken in 1863. This is nine miles west of Peking.

designs and coloured yellow. The intervals are filled in with brickwork coated with red plaster. The central tablet displays four Chinese characters cut in white marble and filled in with vermilion, an imperial inscription in honour of Buddhism. This is flanked by two large oblong slabs of faience carved in open-work relief, with a pair of five-clawed imperial dragons in the midst of scrolled clouds, guarding the jewel of the law, which projects in the centre of each slab.

"The symbolism of colour is all important in China. The triple-roofed Temple of Heaven in Peking shines out gorgeously with its purple tiles, surmounted by a huge purple ball; the sacrificial vases of porcelain are all Mazarin blue, and a subdued blue light is given to the interior by hanging Venetians over the window, made of rods of blue glass closely strung together. In the Temple of the Earth, on the contrary, everything is yellow, its typical elemental colour. The roofs of the palaces and the open-work panelled railings of their verandahs are yellow, approaching in tint the deep colour of the yolk of an egg; the princes live in an atmosphere of green. Among Buddhist temples, those of the Lama, the State church, are roofed with yellow; the others under imperial protection are usually green. A general view of Peking from the top of the city wall, which is sixty feet high, shows the picturesque effect of brightly enamelled colours when lit up by the setting sun, the massive roofs of the taller buildings projecting above a thick setting of green trees. S. W. B.

"28 *May* '03."

In a subsequent communication Dr. Bushell explains that "The yellow tiles are always of faience coated with a plain yellow-coloured glaze"; also, that "most of the tiles are plain; but the lowest in each row is flanged, and the flanges are moulded with panels in relief of five-clawed imperial dragons, coated with the same glaze, as in the following diagram:—

"A A A representing three rows of nearly cylindrical tiles overlapping, the lowest cylinder closed with a round medallion panel.

"B B B B—four rows of flat tiles, the lowest tile flanged with a semicircular panel.

"A glance at the roofing of the archway in the photo will show the method better than the rough diagram."

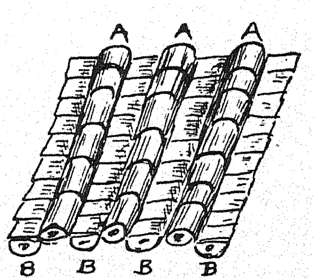


FIG. 81.—Chinese roof-tiles.

In reply to an inquiry as to the mode of manufacture of the Chinese red glaze, Dr. Bushell explains:—

"The Chinese copper-red glaze of the *grand feu* is made from metallic copper. The molten metal, generally derived from the cupellation

of silver, is granulated by being thrown into water, then pulverized, and mixed with a glaze composed of felspar and carbonate of lime, to which amethystine quartz or carnelian is occasionally added. This highly siliceous glaze must be fired in a reducing atmosphere. The firing is said to be a most delicate operation, and must be stopped at the critical moment to attain a bright, uniform ruby-red colour; if it be pushed too high, the metal will be dissipated and the vase will come out wholly or partially colourless; if it is insufficient, the piece will be dull or liver-coloured. . . . . The ruby glaze comes out well on Canton stoneware as well as on ordinary Chinese faience, although rarely used. . . . . The ruby red is the red of the *grand feu*, fired within saggars in the open kiln. The reducing atmosphere is gained, I believe, by selecting the smoky part of the kiln; but the method often fails, and patches of apple green appear from superoxidation, or occasionally the whole vase comes out marbled with flashed tones of darker green. The Chinese reds of the muffled stove are the coral red of iron oxide and the crimsons and pinks derived from gold. . . . . The Chinese work by rule of thumb, not by your scientific principles, and it is marvellous how they sometimes succeed so well."

A very interesting example of Chinese porcelain tiles exists in the Public Museum, Pall Mall, Hanley, in the form of a screen composed of tiles fixed in a wooden frame, as shown in the illustration, kindly permitted by the Museum Committee (Plate XVIII.).

The screen is said to have been purchased by the Museum Authorities on 6th March 1896, but had been exhibited there on loan some years before. It is said to have formerly belonged to a Mr. John Walley.

The tiles are for the most part most carefully and elaborately painted in brilliant colours and gold enrichments, the border tiles being in cobalt-blue colour only. A copy of the photograph was submitted to Dr. Stephen W. Bushell, C.M.G., M.D., who very generously wrote of it as follows:—"It is a good example of the decorative value of porcelain tiles. But the Chinese characters are too small in the photograph to be read distinctly, although I can make out some of them with a lens. The upper panels represent a series of Taoist stories and legends, accompanied by inscriptions in rhyming stanzas, with seven characters in each line. The fourth from the right, for example (above the Taoist immortal Chung-li Ch'uan), represents a visit of Chih Nü, 織女, the 'Spinning Damsel,' and Lyra, on the seventh day of the seventh month, 七夕, to the celebrated Tzŭ-yi, 子儀. Kuo Tzŭ-yi, A.D. 697–781, was one of the most renowned among Chinese generals, and greatly distinguished by his services to four successive emperors of the T'ang dynasty. He was blessed with a numerous progeny, the offspring of eight sons and seven sons-in-law, all of whom occupied high official posts. The blessings which he enjoyed, namely, honours, riches, and longevity, were attributed by a

PL. XVII.

Arched gateway (Pai-lou) at Wo-Fo-Ssŭ. The temple of the recumbent Buddha 18 miles west of the city of Peking.
(*From a photograph kindly lent by Dr. S. W. Bushell, C.M.G., M.D.*)

popular legend to the interposition of the star-maiden Chih Nü, who is said to have appeared to him once on the day specially consecrated as her festival, and promised him these rewards. (See Mayer's *Chinese Reader's Manual*, p. 96.)

"Notice the attendant offering peaches, the fruit of immortality, in a salver; and the pine, the Taoist tree of long life, in the background of most of the pictures.

"The lowest panels present the eight Taoist genii, Pa Hsien, recognised by their emblems, with commemorative couplets of two lines of five characters attached to each. They are, counting from right to left:—

"1. Han Hsiang Tzŭ, with a flute.
"2. Lü Tung-pin, with a sword.
"3. Chang Kuo Lao, with musical rods.
"4. Chung-li Ch'uan, with a feather fan.
"5. Li T'ieh-Kuai, with iron crutch and gourd.
"6. Ts'ao Kuo-ch'iu, with castanets.
"7. Ho Hsien Ku, with a lotus.
"8. Lan Ts'ai-ho, with a basket of peaches.

"Your very truly,

(Signed) "S. W. BUSHELL."

Dr. Bushell further kindly informs me that Canton stoneware is largely used architecturally in South China, and so is the Kochi faience in its native country of Kochi.

Herbert W. L. Way, Esq., of Great Yelkham, in reply to inquiry as to the use of glazed tiles in China at the present time, replied:—"In answer to your question *re* glazed tiles, I may say that I have never seen them used except for roofing and for ornamental designs on roofs . . . . never on walls or floors. I copied several designs in China, used in mats and woven bamboo, which are purely Chinese, and which often struck me as eminently suited for tile flooring, but found they were conventional designs in this country."

The Rev. G. A. Schneider, M.A., in a brief sketch of the history of Chinese porcelain published in Mr. F. W. Phillips' catalogue, says:—"Marble and stone are not much used for decorative purposes; it is pottery which serves as an embellishment of the house. Enamelled tiles are worked into columns and galleries and balustrades; painted plaques enrich the walls of the interior. Every gentleman has his reception-room; and here the furniture consists solely of *étagères* laden with vases of flowers and with dishes of fruit. So, too, there is in every house a shrine for private worship: an altar-table is placed before a religious picture, and this is furnished with articles of porcelain. . . . It must also be remembered that in China rigid social laws determine many a thing which with us is left to the taste and fancy of the individual. No one

in China would dare to select arbitrarily the colour of the tiles on his roof or of the decorations in his house; these matters are fixed according to his station in life. The various dynasties, too, have adopted peculiar colours: the Ming dynasty took green as their livery, the present dynasty yellow, and no one but the emperor has a right to possess yellow vases or table services." The same author tells us that Chinese design, too, is greatly influenced by social custom and religious belief, many of their designs being in reality representations of mythical and fantastic animals, largely emblematic. The dragon, which is supposed to show itself only on extraordinary occasions, such as the birth of an emperor, is represented with five claws on pieces of ware destined for imperial use, with four claws on ware for princes, and with only three claws for wares made and decorated for ordinary commerce. The dog of Fo (Kylin), the defender of temples and altars, has a grinning face with sharp teeth, and its feet are armed with claws.

Yuan Chen, of the Chinese Embassy, London, very kindly informs me that "the use of decorative tiles in covering the roof of a building is only allowed to certain princes and ecclesiastical bodies," and that "decorative tiles, yellow or green, are greatly used by privileged persons in covering roofs of their buildings. The use of such tiles in other ways than the one mentioned is not restricted, but there is no occasion for it. No residential house is furnished with fireplaces as it is in this country; and that being so, its use must be more limited in China than it is here.

Japanese.—According to E. H. Parker, Esq., Japan appears to have been a *terra incognita* even to their near neighbours, the Chinese, about B.C. 222; and western Europeans would know little of Japan until the seventeenth century A.D.

A careful perusal of the several lectures before the Society of Arts, by Ernest Hart, D.C.L., in 1892 and 1895, shows that, although coarse pottery of a useful kind was made in Japan from A.D. 998, or probably earlier, porcelain and art pottery were not manufactured until early in the sixteenth century, when Shonzin went from Japan to China to learn the secrets of the Foochow kilns.

In the later sixteenth and in the seventeenth century various chiefs of Japan invaded Korea from time to time, and either induced or compelled Korean artisans to return with them to Japan. Among these artisans were several skilful potters. From such beginnings arose an industry for which even Mr. Ernest Hart seems scarcely able to find language in which to adequately express his admiration. Yet, in the whole course of his exhaustive lectures, including many quotations from Captain Brinkley's work, not a word about decorative tiles past or present is to be found.

Professor R. W. Atkinson, B.Sc., F.I.C., F.C.S., of Cardiff, who for several years resided in Tokio, has very courteously written as follows:—"The

Screen of Chinese porcelain tiles. (Hanley Museum.)
(By permission of the Museum Committee.)

Japanese in their native buildings do not use glazed tiles or other architectural faience, as practically all their buildings are of wood ornamented with lacquer of different colours. The roofs of their temples are of copper, and all ornaments are of metal or lacquer. The only cases in which anything of the nature of pottery is used (excluding newly erected foreign buildings) are in the walls surrounding the ancient nobles' yashikis (domains), where round cylindrical tiles are used bearing the owner's crest on the ends." The foregoing, of course, applies only to decorative tiles and architectural faience; so far as ordinary pottery and porcelain are concerned, the Japanese are very clever, and Professor Atkinson remarks:—" There is hardly a province in which better or worse ware is not produced."

English Mediæval.—During the thirteenth, fourteenth, and fifteenth centuries ornamental tiles, variously known as "monastic," "encaustic," or "Gothic" tiles, were extensively used for pavements in the interior of English abbeys and churches. As to their first appearance, Dr. Frank Renaud, F.S.A., in his paper on "The Uses and Teachings of Ancient Encaustic Tiles," remarks:—"My own observations, founded on nearly five hundred collected tracings, incline me to think the earliest specimens of monastic tiles cannot be traced further back than towards the close of the twelfth century, and that endeavours to link them with classical pavements would prove abortive." (*Trans. Lanc. and Ches. Antiq. Soc.*, vol. ix. 1891.)

According to Spon's *Encyclopedia*, some of the best examples of these tiles were found at Salisbury, Winchester, Exeter, Bristol, Chichester, Oxford, and Gloucester, one of the most perfect pavements being the floor of the Chapter House at Westminster Abbey. Specimens are also said to have been found at Meaux Abbey, Salley Abbey, Fountains Abbey, Bylands Abbey, Little Marlow Priory, Lewes Priory, Chertsey, and many other places.

"Whether the art was indigenous to England," says Dr. Renaud, "or introduced from France, cannot be determined in the absence of written testimony; but as early examples have been found in Normandy, and early English architecture followed in the wake of Archbishop Lanfranc's coming into England, the balance is in favour of a foreign origin." (*Trans. L. and C. Antiq. Soc.*, 1891.)

Dr. Renaud classifies these tiles under five groups:—Armorial, Pictorial, Symbolical, Moral, and Educational; and shows where examples have been found, and illustrates the tiles themselves by numerous coloured plates.

Other notices of these tiles have appeared in the transactions of various archæological and antiquarian societies, and in journals such as the *Gentleman's Magazine*.

Of special works on the subject there are several; for instance, a large and beautiful collection of coloured drawings in three volumes is to be

found at the Society of Antiquaries, Burlington House, London, illustrating tiles of mediæval age, of many localities in England.

Then there is a work published by J. G. Nicholls in 1845, for whose fidelity in illustration of these things Dr. Renaud personally vouches.

The work by H. Shaw, published 1858, contains illustrations on a reduced scale, but in chronological order; and another by Oldham relates more particularly to a series of tiles found in St. Patrick's Cathedral, Dublin.

With respect to Shaw's work (which may be seen in Birmingham Reference Library), it is quite a revelation to any who think two colours without blending are incapable of effective use for ornamental purposes, and that monastic tiles were originally but sorry products. Someone has facetiously observed, however, that possibly Shaw has done these tiles more than justice, but there may be some justification in trying to represent them as they were. A plate of excellent illustrations of these tiles appears in Lacroix's *Art in the Middle Ages*, of which Messrs. Chapman & Hall publish an English translation.

Dr. Forrer, in his *Geschichte der europäischen Fliesen-Keramik vom Mittelalter*, reproduces on his plate v. Shaw's drawing for English inlaid tiles of thirteenth century from Chertsey Abbey (Surrey), and these appear in brilliant contrast to the German tiles of a like age.

In the Guildhall Museum, London, a very large number of specimens are preserved. They are classed as tiles of red earth of the twelfth to the seventeenth centuries, and are described as being, with very few exceptions, of square form, $4\frac{1}{2}$ to 5 inches square and about $\frac{3}{4}$-inch thick. The ornamentation is very varied and typical of the period, full of allegory, heraldry, and symbol. This is most usually effected by inlaid clay, sometimes glazed; sometimes level, at others, recessed, or, again, in relief. Representations of arms, shields of arms, fleur-de-lis, interlaced triangles, five-petalled flowers, trefoils, quatrefoils, cinquefoils, multifoils, segments of circles, cross and chevrons, lozenges, pellets, scrolls, seem to be the most common elements of ornament.

Considerable numbers of those in Guildhall Museum were derived from St. Matthew's Church, Friday Street; Brook's Wharf; Royal Exchange; City of London; and St. Andrew's Church, Chinnon, Oxfordshire.

Malvern claims to have an exceptionally fine collection of monastic encaustic tiles, both conventional and heraldic, of the fourteenth and fifteenth centuries, now on the walls and pillars of the Priory Church. They are supposed to have formed the original pavement of the church when it was erected in the fifteenth century; and its richness and beauty must have been remarkable, for at least one hundred different designs have been noted, including the armorial bearings of various important families who were associated with Malvern in mediæval times.

The illustration is a view of some of these tiles as now seen in the Priory Church. Many such tiles are supposed to have been made in a monastic establishment here during the fifteenth century, and it is said that in 1833 a kiln for burning encaustic tiles was discovered within 200 yards of the church.

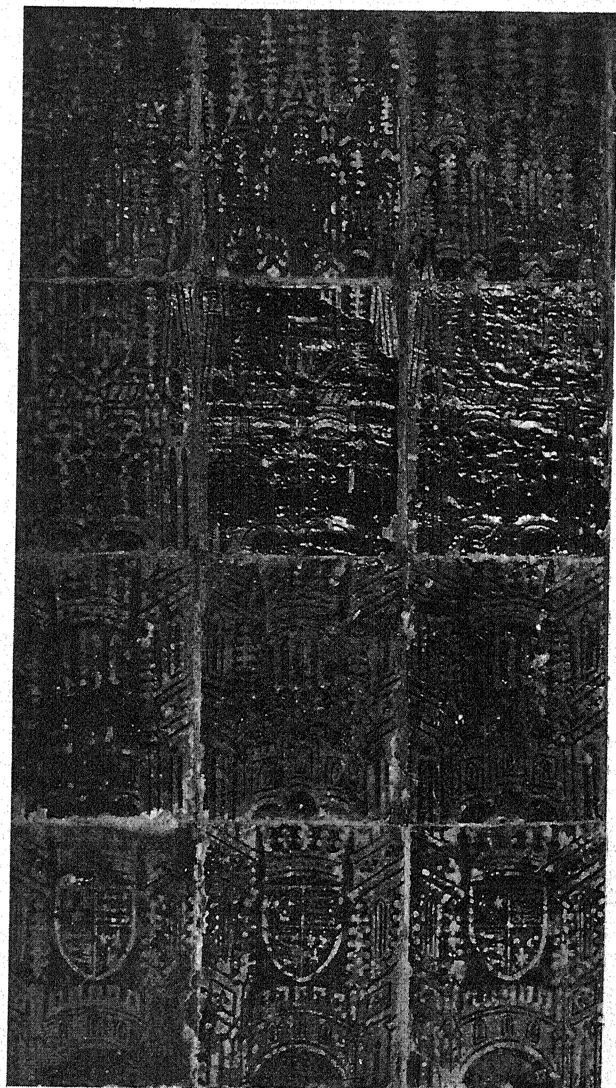


Photo by Norman May & Co.] [*Malvern.*

FIG. 82.—Mediæval tilework in Malvern Priory Church.

At Bristol, the Cathedral authorities—thanks mostly to Robert Hall Warren, Esq., F.S.A.—now have a fine collection of mediæval tiles, which have been figured and described in the *Proceedings of the Clifton Antiquarian Club*, vol. v. p. 122. Mr. Warren states that the various alterations since the dissolution of the abbey have resulted in the utter breaking up of the pavements and the dispersion of the tiles. The illustrations, which we are generously permitted to make use of, were originally traced, reduced, and drawn by Miss Warren, daughter of Robert Hall Warren, Esq., of Clifton. They represent specimens from several collections, in addition to those in the Cathedral, and drawings of other tiles, of which the originals cannot now be traced.

No. 1 has a shield of the Berkeley arms, with a sprig of thirteenth-century

stiff leaf-foliage springing from the top and on either side. The tile is 5 inches square by ⅞-inch thick. Six similar tiles were found in Harrington Church, Northamptonshire.

No. 2 is one of the many varieties of the bird and foliage type, traced from a tile now in the north aisle of the choir.

Nos. 3 and 4 are of thirteenth-century character, and of similar design to some in Salisbury Cathedral and in Merton College, Oxford.

Nos. 7 to 10 are all assigned to the thirteenth century.

Nos. 11 to 24 Mr. Warren says are apparently of fourteenth-century character, and are all decorative.

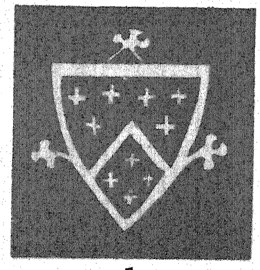
Nos. 25 to 33 Mr. Warren attributes to the fifteenth century, and supposes they were made at Malvern for Abbat John Newland and his successor Robert Elyot.

As may be anticipated, several of the tiles are in a mutilated condition, and their sequence is often only traceable by finding other members of the sets in other localities. Where this has been done, the legend usually proves to be scriptural.

In the Bristol Museum there are similar tiles from the site of the destroyed Keynsham Abbey, but they are not shown in the museum at present for want of room, and have not been figured. Mr. Warren, at a meeting of the Clifton Antiquarian Club, stated that "The thirty-eight which I have here illustrated compare very favourably with the twenty-four varieties which Mr. Loftus Brock exhibited from Keynsham Abbey . . . . and are good examples of every type from the thirteenth to the sixteenth centuries, from the time when this form of pavement first prevailed in England to the time when the church-building age was over, and what few tiles were required were imported from Flanders, to be succeeded by plain stones or squares of black and white marble." (*Proceedings of Clifton Antiquarian Club*, vol. v. p. 122.)

Then there are also in the possession of the Corporation of Bristol specimens of tiles which originally belonged to what is called the "Mayor's Chapel" at Bristol; this was originally the college chapel of a monastic institution known as The Gaunt's Hospital, dating from 1230. Alderman W. R. Barker, J.P., Chairman of the Bristol Museum Committee, to whom the writer, with greatest pleasure, acknowledges his indebtedness for the whole of this interesting information about these mediæval tiles of Bristol, has written a book about this interesting thirteenth-century foundation, from which we learn that "on removing the rough ground immediately outside the line of the transept arch a number of decorative tiles were found . . . . near the surface, and which consequently had suffered to the full extent from violence and exposure. . . . . Some of them were fortunately whole and their devices more or less preserved, though bearing the marks of great age. Many

Pl. XIX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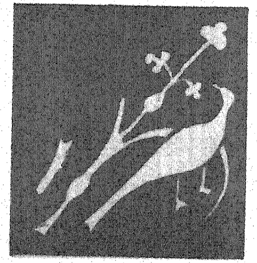
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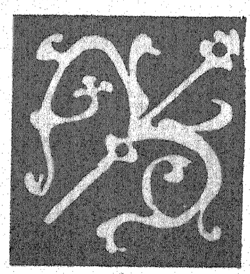
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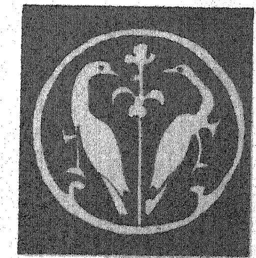
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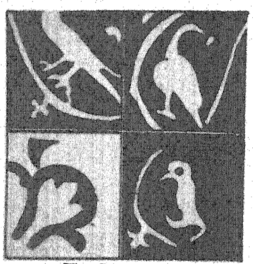
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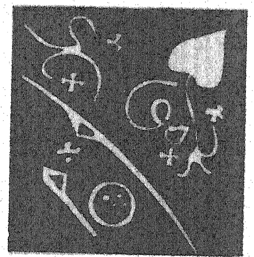
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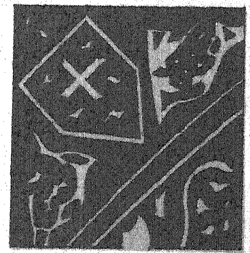
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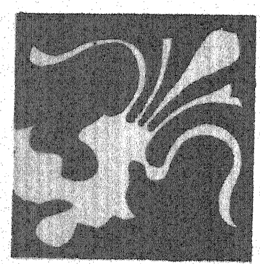
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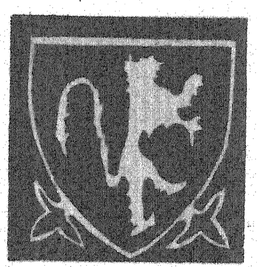
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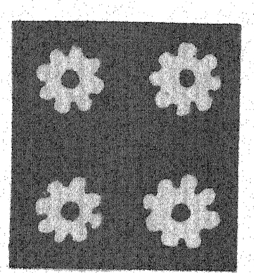
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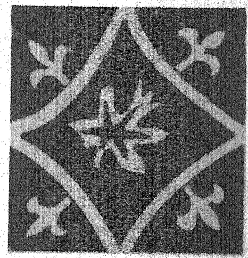
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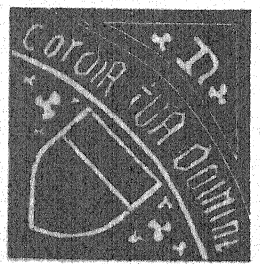
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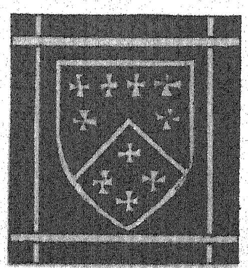
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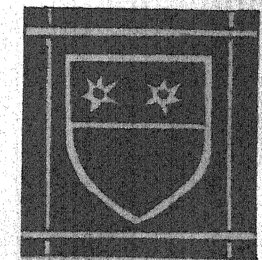
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LAVARS & C° LITH. BROAD ST BRISTOL.

From Drawings by Miss Warren, of Clifton. Reprinted by kind permission of Robt. Hall Warren, Esq., F.S.A., and Alfd. E. Hudd, Esq., F.S.A., of the Clifton Antiquarian Club.

others were broken to fragments and past all identification. . . . . One is a broken specimen with the royal arms, and may be referred to Henry III., in whose reign the hospital was founded, and whose eldest son Edward was himself one of its benefactors.

"There are two whole specimens with the arms of the Berkeleys, besides many fragments on which their crosslets appear. . . . . Another specimen has the well-known arms of de Clare, Earl of Gloster. Another, those of William the Marshall, Earl of Pembroke. . . . . In addition to the tiles with armorial devices, there are others with representations of various animals, others with birds and trees, and others again with the geometrical patterns appertaining to an ecclesiastical building. In addition to the tiles, there was a large quantity of narrow tile-bordering; the quantity being quite out of proportion to the number of tiles remaining, many tiles must, therefore, at some time have been removed." (*St. Mark's, or The Mayor's Chapel*, pp. 126, 127.)

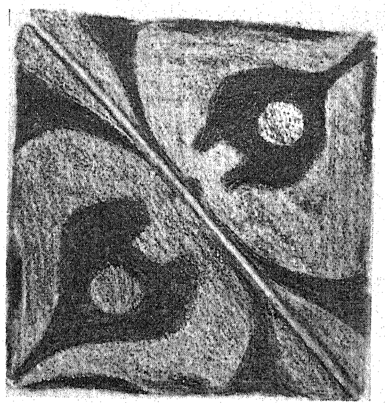


FIG. 83.—Hulton Abbey tiles. Hanley County Borough Museum.

In York Museum a fine series is exhibited, mostly tiles about 4 or 5 inches square, some of which are believed to have been made at Malvern, and others at Repton. Tiles made at Repton (Derbyshire) are said to have been used in the pavements of both York Minster and St. Mary's Abbey, York.

In the Grosvenor Museum, Chester, sixty-one such tiles are shown.

In Hanley Public Museum there are fourteen or more specimens of monastic tiles, which were dug up from the ruins of Hulton Abbey. This abbey was founded A.D. 1223, and for three hundred years held social and spiritual power in the locality. It was closed about three hundred and fifty years ago, and now scarcely a stone is left above-ground in its original position, the site being mostly occupied by farm buildings.

In Lichfield Cathedral the corner of the consistory court is paved with mediæval tiles, said to have originally formed part of the Cathedral floor, prior to the restoration in A.D. 1661–70. The floor of the Cathedral library, too, is paved with old encaustic tiles, supposed to have been laid about 1673. Of some of these the red body is much worn away, leaving the buff-coloured encaustic-inlaid pattern raised.

In the Lady Chapel, also on the floor of one of the small chapels, may be seen some of the old encaustic tiles.

At one time part of the Cathedral floor was paved with cannel coal

and alabaster. (See Harradine's *Hand Guide to Lichfield Cathedral*, p. 58, Lomax.)

From Sir W. B. Richmond we learn that in mediæval times art was not lavished on the floors alone, for he says:—"Two thousand churches in England now . . . . retain vestiges of mediæval painting." (*Builder*, 14th March 1903, p. 284.)

Monastic tiles were most usually made of red burning clay for a main body, having the ornament of yellow burning clay; these two primary colours thus forming a strong contrast. The yellow clay was inlaid probably in a slip state in the tile while in a soft plastic state, an impression of the pattern being first made. Some were glazed over the whole surface, others only on the pattern or figure. A few were in relief.

Langenbeck has facetiously remarked:—"The tiles for the old English cathedrals were burned in little beehive ovens but 5 feet or 6 feet in diameter and 3 feet high. The tiler had to crawl in on his hands and knees to set the ware, and the great floors were laid with practically all the product without sizing or shading. As we look at them to-day they are still satisfying. The jointing, large enough to take up the inequalities in size, gives a texture to the floor; the variations in shade a liveliness of colour." (*British Clayworker*, July 1899.)

Italian Mediæval and Renaissance.—Many of the examples of Italian ceramics to be seen in British museums consist of portable articles, such as were produced in great quantity during the Renaissance period—vases, drug-pots, plates, dishes, tazzas, and the like.

The want of mobility, and more limited production of large decorative pieces, render their appearance, out of Italy, less frequent; yet, along with the general movement in the direction of more lavish embellishment of European churches during the fourteenth and fifteenth centuries, Italy took her part; not so much perhaps in the use of tiles after the manner of Mohammadans, as in more pretentious allegorical and historical representations, often of religious signification, in some measure recalling the works of Assyria and Susiana, except for the difference of *motif*.

According to Passeri, the façades of the Churches of St. Agostino, Duomo, and San Francesco, presumably at Pesaro, were adorned with coloured plates of glazed pottery of native manufacture about the thirteenth century (see Marryat's *History of Pottery and Porcelain*, p. 13); and churches in Bologna, Pisa, Ancona, and Tolentino are also reputed to have been similarly embellished.

The manufacture of glazed ware seems to have begun in Italy as early as A.D. 1100; and some time between 1100 and 1300 *mezza-majolica* was made. This, W. De Morgan says, was not engobed with tin-oxide enamel, but with a clay-slip prepared from a very white earth obtained from Siena, the whole

being afterwards covered with glaze called *marza-cotta,* containing compounds of lead and alkali. The use of such a clay-slip lends plausibility to the idea that any ultra-Italian influence in operation at this period was Syrian rather than Moorish.[1] And as the maritime supremacy of Venice made Italy the channel of vast commerce from the East, Eastern influence was certain to be felt.

Undoubtedly Moorish influence eventually shared in building up the art in Italy, partly resulting from crusades by the Pisans against the Moors of the Balearic Isles, A.D. 1113–1115, and partly by ordinary commercial intercourse. Thus, in his *History of the Reign of Ferdinand and Isabella,* Prescott has the following:—"Silk furnished the principal staple of a traffic that was carried on through the ports of Almeria and Malaga. The Italian cities, then rising into opulence, derived their principal skill in this elegant manufacture from the Spanish Arabs. Florence, in particular, imported large quantities of the raw material from them as late as the fifteenth century. The Genoese are mentioned as having mercantile establishments in Granada." (*Spanish Pictures*, p. 135, R.T.S.)

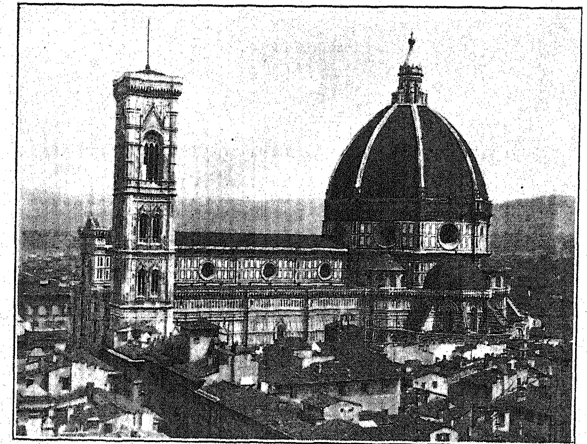
If, then, between A.D. 1300 and 1500 Florence and Genoa were thus intimately associated with Moorish Spain, what more natural than they should import and emulate their ceramic products as they did their silken fabrics? Indeed, Fortnum especially asserts that "these wares were largely imported into Italy, where they were known as maiolica di Valencia." (*Catalogue of the Maiolica, Ashmolean Museum*, p. 12.) Further, he remarks:—"The introduction of the stanniferous enamel was a great advance upon the ruder process of the white clay-slip. This method, probably introduced by or learnt from Moorish potters, is proved to have been known at Faenza in the later years of the fourteenth century. It was practised in Tuscany by Luca della Robbia as early as the first quarter of the fifteenth century. . . . That he was its inventor is a myth long supported by many writers, but for which there is no solid foundation. . . . From the researches of Prof. Argnani, we learn that at Faenza it was in use as early as 1393. . . . The application of metallic lustre in Italy seems also to have been derived from Saracenic or Moorish potters. . . . It is not unreasonable to suppose that Pesaro, a sea-coast town having established potteries, might have been reached by some Oriental potters, fugitives from Sicily or Spain, fleeing from persecution or seeking employ, who, after working some few years at Pesaro, may have passed on, some to Gubbio, others to Diruta, at each of which places their art may have been imparted, and subsequently practised by Italian potters." (*Catalogue, Maiolica, Ashmolean Museum*, pp. 13, 14, and 19.)

Had it not been that the tin-oxide enamel, as W. De Morgan informs us,

[1] An Italian majolica dish, illustrated by Prof. Binns on p. 71, *Story of the Potter*, is distinctly Syrian or Cairene in *motif* or style of ornamentation.

was not used by the Italians exactly as the Moors used it, but simply as a whiter substitute for the white slip, upon which improved substitute the Italians continued to superimpose the marza-cotta glaze, precisely as they had hitherto done on the old ground, we might have considered the probability of direct Moorish teaching very great.

It is not in the least unlikely that the makers in the several different glazed-ware-making districts worked concurrently by different methods, precisely as is done in Great Britain and other countries to-day, either by reason of the habit of the operatives, the nature of the available materials, or the kind of appliances. Thus these varied products would readily resemble Persian or Moorish products according to the practice of the artists. "But if Italian potters took the idea from foreigners," wrote Marryat, "they soon surpassed their instructors, as is clearly proved by a comparison of the coarse paste and rude arabesque patterns of the one with the fine paste and finished compositions of the other." (*Pottery and Porcelain*, p. 15.)



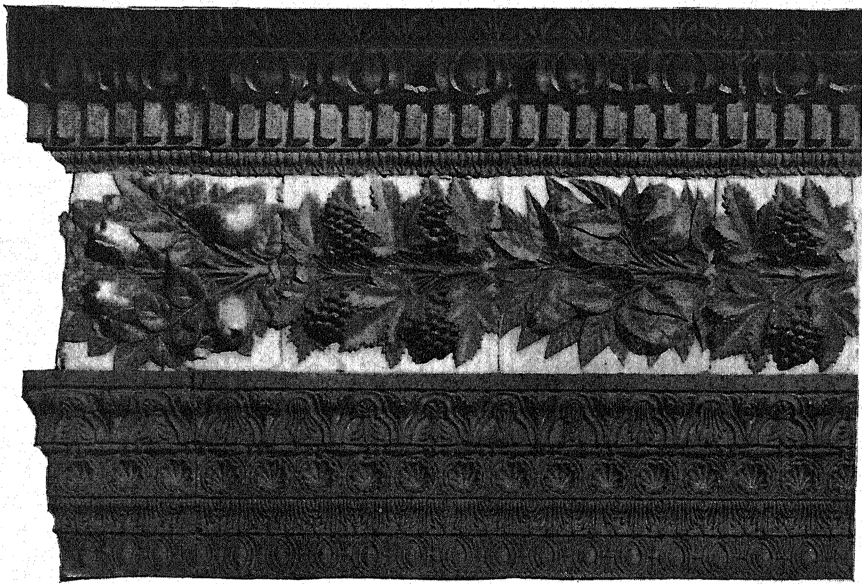
Alinari, photo.] [*Firenze.*

FIG. 84.—The Duomo, Florence.

The most illustrious personage in this department of Italian mediæval art is, of course, Luca della Robbia of Firenze. Our hero, if we may venture the term, was born about A.D. 1400, and had the advantage of beginning his career in one of the most palatial cities of Italy. The precise nature of his early training is not clearly traceable. Some have supposed he began his working life as a goldsmith, but Miss Maud Cruttwell, in her very instructive and entertaining book about the Della Robbias, expresses the opinion that the balance of probabilities is in favour of believing that Luca's early artistic training began under Lorenzo Ghiberti, and that Luca della Robbia took a share in the work this noted sculptor was engaged upon about A.D. 1420.

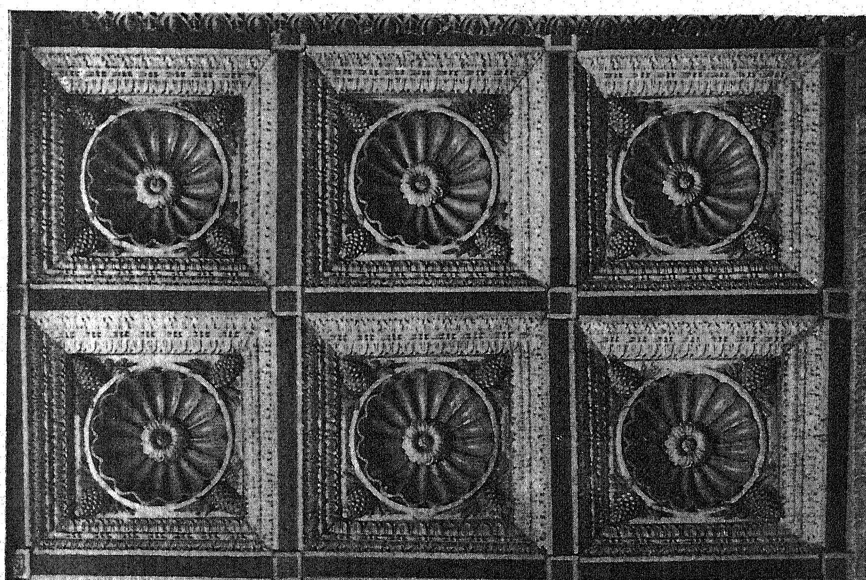
Luca was a sculptor as much as a ceramist, and his whole life's labour seems to have had a religious *motif*, and was largely spent in the service of the Church. Apparently he made no attempt at manufacture as we understand the term, and rarely repeated a work.

He prepared certain specific decorative works, either in marble, in bronze,



Alinari, photo.] [*Firenze.*

FIG. 85.—Portion of frieze in the Chapelle de Madonna, Impruneta.



Alinari, photo.] [*Firenze.*

FIG. 86.—Portion of coffered roof in the Chapelle de Madonna, Impruneta.

or in enamelled terracotta, according as he was commissioned by the authorities. His eminence can well be imagined from the fact that the high dignitaries of the cathedral should associate him with that prince of sculptors, Donatello, in the adornment of the Duomo, when the cities of Italy were vying which should possess the most beautiful church. Miss Cruttwell pictures Luca della Robbia as a refined idealist, severe for his times, never swerving from all that is true, simple, and direct in art. On the best authority she leads us to infer that Luca permitted no repetitions of his work, and no collaboration in his designs, although he carefully taught his nephew Andrea the art, and frequently allowed him to share the labour of actual production. Luca's fame, although arising mostly from his ceramic products, rests largely also upon his bronzes and his marble sculptures; as, for instance, the cathedral doors of bronze and the cantoria in marble; these seem to have been his really greatest achievements. So far as his enamels are concerned, Miss Cruttwell asserts that whatever secret there was about them, lay in his infinite capacity for taking pains.

Alinari, photo.] [*Firenze.*

FIG. 87.—Luca della Robbia.

Of his work in the Pazzi Chapel, S. Croce (Firenze), she writes :—" For the first time we see Luca the sculptor working in close collaboration with the architect, for the decorations form an integral part of the building, not only in the atrium, where the small cupola is entirely encrusted with enamelled ornaments, but within the chapel itself, where the medallions are rather a part

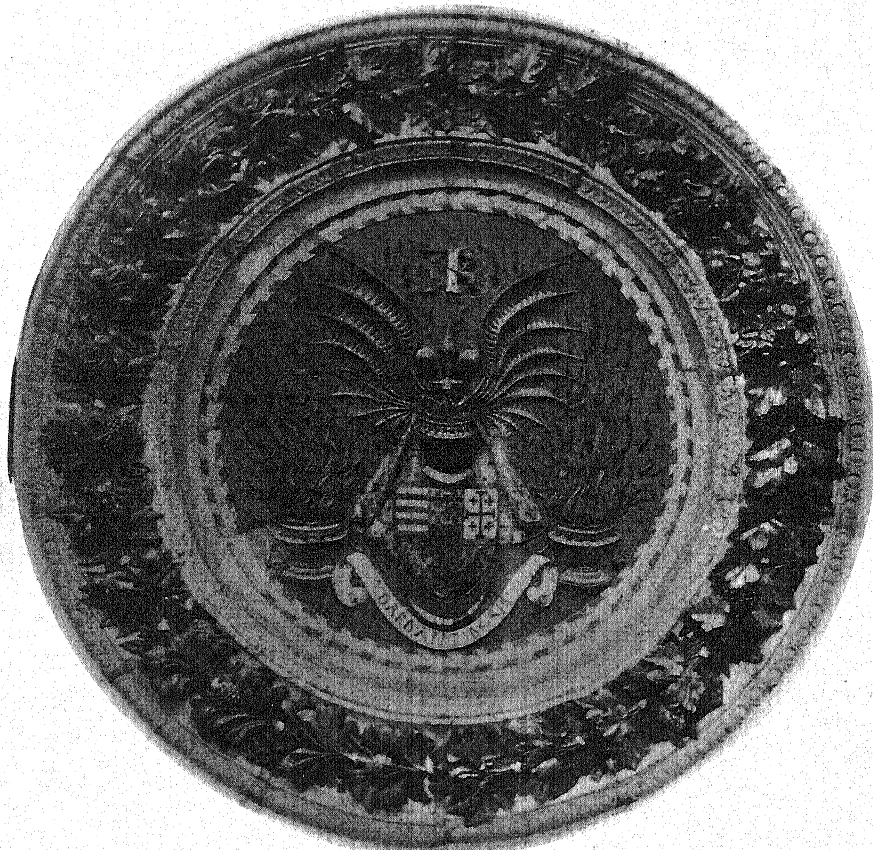


FIG. 88.—Stemma of René d'Anjou, eleven feet diameter. South Kensington Museum.

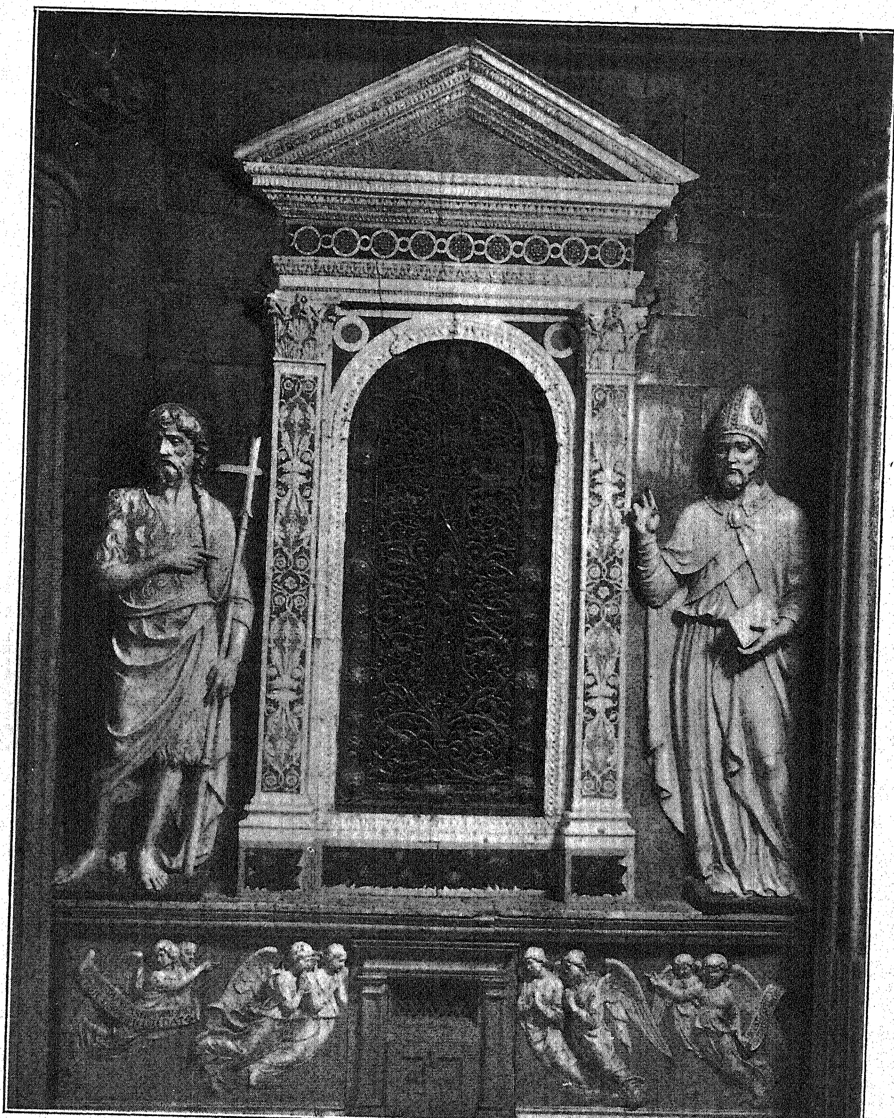
of the architectural design than independent sculptures. . . . . In the Pazzi Chapel, the building seems but a splendid setting or framework for Luca's medallions. As we enter the cloister, and walk slowly towards the entrance of the chapel, the beautiful decoration of the little dome reveals itself gradually like the unfolding of some exquisite flower, the pure brilliant colours gaining full value by contrast with the grey of the *pietra serena*." (*Luca and Andrea Della Robbia*, p. 73, Dent & Co.)

In the Victoria and Albert Museum, South Kensington, there are said to be more than fifty examples of enamelled terracotta known as Della Robbia ware, one of the finest being a medallion, eleven feet diameter, bearing the arms and emblems of King René d'Anjou, surrounded by a massive border of fruit and foliage (fig. 88). It is made up of sections, as will be observed upon closely scrutinizing the illustration. The prevailing enamels are pale blue, and the white for which Luca was so famed. The date of manufacture is supposed to have been about 1453; it was originally fixed in an exterior wall of a villa in Firenze in memory of a visit of the king. In that situation it had remained exposed to the action of the atmosphere for more than four hundred years. A few years ago it was obtained for the South Kensington Museum, where it may now be seen. (*V. and A. M. Catalogue*, p. 26.)

Miss Cruttwell is eloquent in her praise of Luca's works of this class. She writes:—"We now come to a group of works in which Luca, abandoning for the moment the nobler form of sculpture, lent his genius to heraldic decoration. . . . . The largest and in every respect the finest of these *stemmi* is the medallion in South Kensington Museum with the arms of René d'Anjou. Never was mere decoration endowed with such vivid, flaming life. The great wings of the helmet strike out on either side, spinous and strong like the pinions of an eagle; the tongues of flame shoot up from the braziers, darting their points and scattering their sparks like wind-shaken embers. The whole work is as vivid with flash and flicker as the fire-music of the *Götterdämmerung*, and around all this scintillating movement flows rhythmically and tranquilly the beautiful garland of leaves and fruits." (*Luca and Andrea Della Robbia*, p. 101, Dent & Co.)

An equally eloquent analysis of the garland follows, "without comparison the finest of the garlands." For this our readers must please refer to the original.

Respecting the tabernacle (fig. 89), Miss Cruttwell explains that it is entirely of enamelled terracotta of various hues, and that the groups of pine-cones painted in the base of the frame is the only flat-surface painting we have from Luca's brush which is not conventional and only decorative. On either side stand St. John the Baptist and St. Augustine; one of these she supposes to have been the work of Andrea della Robbia. "The Predella below is by Luca himself, and is one of his most beautiful reliefs. . . . . This



Alinari, photo.] [*Firenze.*

FIG. 89.—Tabernacle in the Chapel of the Holy Cross, Impruneta. *By Luca and Andrea della Robbia.*

Predella with its shrine *was* the principal part and focus of the tabernacle, the receptacle of the Holy Sacrament which the whole altar-piece was executed to enclose." (*Ibid.*, p. 114.)

Of the lost works of Luca della Robbia, Miss Cruttwell writes:—"Most important of all the perished works must have been the decoration of the cabinet of Cosimo de Medici in the Palazzo now called the Riccardi, of which also no trace remains. Vasari's description of the chamber is worth quoting:—'Piero de Medici commissioned Luca to cover all the roof of a study, built by his father Cosimo, with enamelled terracotta in relief, with numerous fantasies, and likewise the pavement, a rare thing and very useful for summer-time. And it is certainly marvellous. . . . .' The decoration must have been completed before 1464, for Filante, in his treatise on architecture dedicated in that year to Piero, alludes to it in these words:—'The small, highly decorated study of Cosimo, both pavement and roof of glazed work, done with most excellent pictures, so that everyone who entered marvelled greatly. The artist was Luca della Robbia . . . . a most excellent master in this art as well as in sculpture.' These are the sole records we have of the only piece of domestic architectural decoration executed by Luca, and no fragments have been discovered that might have belonged to it." (*Luca and Andrea Della Robbia and their Successors*, p. 130, Dent & Co.)

For information about the ceramic productions of Andrea della Robbia, Luca's nephew and successor, we look again to the volume so patiently and so thoroughly compiled by Miss Cruttwell. Until the death of Luca in A.D. 1482, Andrea apparently was his constant pupil, companion, and helpmate. Not naturally possessed of the stately genius of his uncle, Andrea yet acquired a grace and sweetness of expression peculiarly his own; and Miss Cruttwell admits that Andrea's popularity in our day even exceeds that of Luca himself.

Halsey Ricardo has even asserted that "Andrea's work *quâ* pottery is everywhere superior to Luca's."

"For children Andrea has special sympathy," writes Miss Cruttwell, "and represents them with greater charm than any other artist of the Renaissance, standing alone among contemporary sculptors and painters as the special interpreter of child-life." (*Luca and Andrea Della Robbia*, p. 141, Dent.)

And what more natural, seeing that Andrea was himself the father of a large family, and would, week in and week out, experience the delights of the winning ways and prattle of his offspring. According to Miss Cruttwell, Andrea was born A.D. 1435, was married 1465, and by 1470 was the happy owner of three sons, the third being Giovanni. After that came four more sons, the last being Girolamo, born 1488.

With regard to Giovanni della Robbia, who was Andrea's third son, and practically his successor in the ceramic art in Italy, Miss Cruttwell certainly

seems a trifle severe and vindictive. In criticising his works she writes thus:—"Giovanni was the most protean of artists, and changed his style as readily as a man of fashion changes his coat. . . . . Giovanni, with all his talent and occasional flashes of genius, sold his birthright for a mess of pottage, and to him is chiefly due the degradation of the Robbia art from its high level to the position of mere potter's work. In the few productions on which he has bestowed care and thought, we find him to have inherited no small share of the artistic gifts of his race, and to be possessed of much individual character and strength. . . . . In his haste to produce, he either allowed himself no time for the development of his own personality, or strove to suppress it as unproductive and superfluous. It was simpler to adopt a ready-made style, already proved popular . . . . than to cultivate the expression of personal thoughts." (*Luca and Andrea Della Robbia*, p. 205, Dent, London.)

In a very interesting closing chapter, Miss Cruttwell describes and discusses the life-incidents and work of Andrea's youngest son Girolamo, who earned distinction by setting forth bravely from his native land to ply his art in France; of this, more shortly.

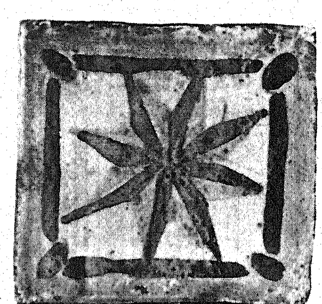


FIG. 90.—Gubbio tile. S.K.M.

A natural sequence of Luca's eminence, and partly an ordinary coincidence, was the use of the same Christian name in succeeding generations of Della Robbias. To one of these namesakes, a later Luca, is attributed the manufacture of a pavement in the Loggia of the Vatican.

But any account of Italian mediæval ceramics would be grievously incomplete without special mention of another notable artist whose genius has left examples of historical portent, viz., Giorgio Andreoli, of Gubbio. This artist, it seems, went from Pavia to Gubbio about 1485. He too was a sculptor as well as a painter, and executed several bas-reliefs in the Della Robbia style; but his reputation chiefly depends upon his majolica plates, which were remarkable for brilliant colouring, in which ruby-red and golden-yellow iridescent effects are most conspicuous. His products are dated from A.D. 1518 to 1537. (*Hist. Pottery and Porcelain*, Marryat.)

W. De Morgan says that Maestro Giorgio's red was a deep transparent crimson, which did not interfere with the painting under the glaze, but was like running a transparent crimson over a monochrome drawing.

It is not necessary to suppose Giorgio invented ruby and yellow lustres. Fortnum thinks it quite likely that the information was imported into Pesaro by Moorish ceramists, who subsequently passed on to Gubbio, and that it was practised there by some expert artist prior to the arrival of Giorgio in Gubbio; and that Giorgio Andreoli had not used the process before he went

there. When, however, he adopted this method of enriching his products, he developed, improved, and made a speciality of it. (*Catalogue of Maiolica in Ashmolean Museum*, p. 19.)

Fortnum makes mention also of several pavements of tiles in Italy, which he refers to mediæval times. At Siena he says tiles were found in the chapel of Sta. Caterina, and in the Petrucci Palace, bearing dates 1504 and 1509. (*Ibid.*, p. 16).

Of Urbino, he says:—"A pavement of tiles in the Vescovado at Padua, ordered in 1491, was executed by Giovanni Antonio and Francesco da Urbino." (*Cat.*, *Ashmolean*, p. 24.)

Of Faenza, he writes:—"One of the most important monuments of Faentine ceramic art is the pavement of the Chapel of St. Sebastian, in S. Petronio at Bologna, the painted and inscribed tiles of which are admirable in design and colouring. . . . . It was made in 1487 by the Bettini of Faenza, Petrus Andreas de Faventia being the artist painter. It is accurately described by Signor L. Frate in his *Di un Pavimento in Maiolica*, etc. (Bologna, 1853), who also described a pavement of similar origin in the Bentivoglis Chapel at S. Giacomo Maggiori in that city. (*Cat. Maiolica, Ashmolean*, p. 31.)

Of Forli, Fortnum refers to several tiles in the South Kensington Museum forming part of a series of examples of Forli wares.

No. 2591 is "a tile on which is the armorial shield of the Ordelaffi Lords of Forli, probably of about 1480–1490." Another is a tile . . . . painted in blue on the white ground . . . . purchased by the writer (Dr. Fortnum) at Forli, 1860. No. 30—166 is "all that remains of a pavement of tiles formerly in a villa at Piere, near Forli; some of the more valuable of which, bear inscription, portrait heads, and the date 1513, are also to be attributed to the same *botega*, and are perhaps by the same hand. Some of those are of yellow and orange colouring painted in *giallo sopra giallo*." (*Cat. Ash. Museum*, p. 34.)

Of Ferrara tiles, he mentions archives of the Ferrarese duke that "inform us that in 1436 and 1472 potters are recorded by name; that in 1443 glazed and painted wares are mentioned; in 1474 the Capella del Cortile had a pavement of painted tiles; and Fortnum says 'some tiles from a pavement, formerly in "La Grotta," are in the South Kensington Museum.'" (*Cat. Maiolica, Ashmolean Museum*, p. 35.)

Of Venice, he tells us:—Glazed architectural ornaments have been found amongst some fragments in foundations; also a pavement of tiles, formerly in the Church of Sta. Elena, is mentioned. (*Cat. Maiolica, Ashmolean*, p. 36.)

Of Naples, he says:—"Of the fifteenth century are the tiles of a pavement in the Church of San Giovanni a Carbonari, which probably are of local production." (*Ibid.*, p. 39.)

Still another name deserves mention in connection with Italian ceramics, viz., that of Piccolpasso, who has laid posterity under some little obligation by describing to the best of his knowledge the processes of manufacture of Italian mediæval maiolica. And although the document may have shortcomings — for W. De Morgan thinks Giorgio's son Cencia hoaxed Piccolpasso in respect of the lustre process—the descriptions and illustrations of the manuscript are interesting. We understand that this original manuscript is in the library of the Victoria and Albert Museum, South Kensington. According to Fortnum, Cipriano Piccolpasso completed his manuscript of the *Arte del Vasaio* in 1550. (*Cat. Mai., Ashmolean*, p. 22.)

By the courtesy of Dr. Forrer, we are able to reprint an illustration from his *Geschichte der europäischen Fliesen-Keramik* (fig. 91) of three majolica tiles from S. Petronio at Bologna, attributed to a period about 1489 to 1495 A.D. The writer understands the learned doctor to say that these faience tiles were manufactured at Faenza, and were used for pavement purposes in the Marsili Chapel of the Church of Saint Petronio at Bologna, at the end of the fifteenth century.

Two other majolica tiles (figs. 92, 93), after Molinier, are from the Church of San Pietro, at Perugia, and of the date 1563.

The tile-pavement of the Petrucchi Palace, Siena, an illustration of which we are permitted to reproduce from

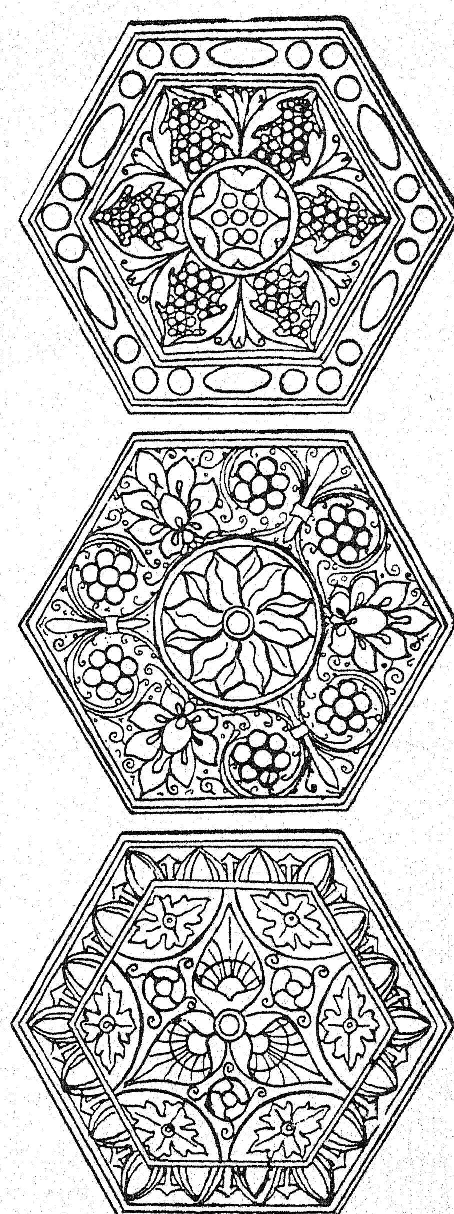


FIG. 91.—Three majolica tiles from S. Petronio, Bologna. (*After Meurer.*) (*By permission of Dr. R. Forrer.*)

the article upon "Decorative Tiles" by Mr. F. W. Phillips (*Connoisseur*, vol. vii. p. 166), is also mentioned and illustrated by Dr. Forrer, who

FIG. 92.—Tile from Perugia. (*By permission of Dr. Forrer.*)

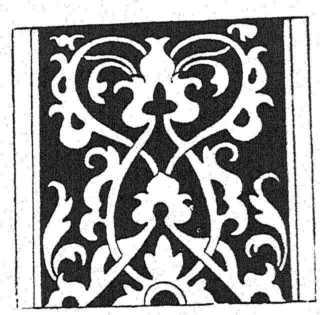


FIG. 93.—Tile from Perugia. (*By permission of Dr. Forrer.*)

attributes its manufacture to Messieurs Benedetto, and dates its manufacture A.D. 1509.

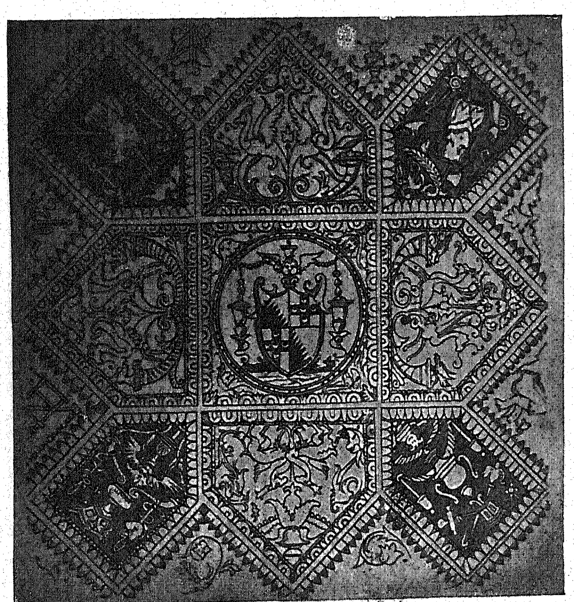


FIG. 94.—Portion of tile-pavement from the Petrucchi Palace, Siena. (*From a print. By permission of the proprietors of "The Connoisseur."*)

After an existence of about three hundred years the majolica manufacture decayed in Italy. This was attributed, among other things, to the caprice of fashion, which, upon the introduction of Oriental porcelain into Italy in the sixteenth century, denounced majolica as vulgar, and porcelain became the rage. Thus, as Passeri regretfully remarked, majolica, which had served the table of kings, embellished temples and spread the honourable fame of Italian fabrics far and wide, was now shorn of renown, and remained only an object of curiosity to collectors of Italian antiquities. (*History of Pottery and Porcelain.*)

German Mediæval and Renaissance.—The ornamental tilework of Germany and Austria between the twelfth and sixteenth centuries appears

to have consisted mostly of square unglazed monochrome tiles in which the surface designs were formed by simple line indentations. These are illustrated on plates vi. to xi. of Dr. Forrer's *Geschichte der europäischen Fliesen-Keramik vom Mittelalter*, from which fig. 95 is taken by his permission. Very few appear to have been glazed, and even more rarely, if ever, are they encaustic-inlaid like those of France and England, although possibly the indentations may in some cases have been coloured to accentuate the effect.

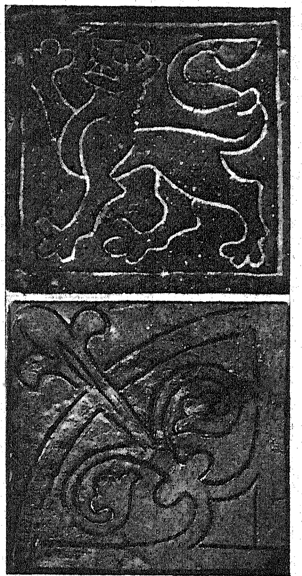


FIG. 95.—Two early German impressed tiles. (*By permission of Dr. Forrer.*)

The designs are very elementary, but evidently had symbolic or heraldic significance, which would impart interest in their age and locality. Some designs are distributed over four tiles, or possibly more, and, when complete, yield a pleasing pattern. On plates ii. and iii. he figures several glazed relief tiles of this period, of coarse Romanesque design, mostly octagonal or rhomboidal shapes, with monochrome glaze of yellow-brown tint, from St. Fides' Church, Schlettstadt (Alsace); also a square tile with pattern composed of two concentric circles, having twelve smaller circles with star centres equally placed around the annular space, and conventional lions in the centre. This is glazed with yellowish-green glaze, and is from St. Odilien's Abbey, Odilienberg, where Dr. Forrer, during the excavations, had the honour of receiving the German Emperor. These early German tiles, however, present a singular contrast to the wonderful delicacy of the tiles from Chertsey Abbey (Surrey) of the thirteenth century, as figured by Shaw.

With regard to enamelled faience, Brongniart dates its introduction into German industry about the year A.D. 1520, locating its earliest centre at Nuremberg (Nuernberg), thus giving it precedence over that of Bernard Palissy in France, which is said to resemble this early German enamelled faience.

The rapidity with which the art appears to have passed from Italy to Germany is accounted for by Marryat in the following circumstantial manner: "Hirschvögel, an artisan of that city (Nuernberg), travelled into Italy in 1503, and went to Urbino, where he learned the art of enamelling pottery. He returned in 1507 and established the first manufactory of majolica; but sculpture and carving being more congenial to his taste than painting, the works he produced are ornamented in relief." (*Hist. Pottery and Porcelain*, p. 115.)

This intercourse with Italy is not in the least remarkable, for we learn from a very interesting description of Nürnberg in the *Leisure Hour*, 1885, that until the discovery of the new passage to the East (presumably by the Cape of Good Hope, A.D. 1498), Nuremberg was the greatest of German marts, had a vast foreign trade, and was the storehouse of the precious Indian wares poured into it from Italy for the north.

According to Marryat, the potters of Nuremberg were especially celebrated for very large glazed tiles for covering and ornamenting stoves, of which he states many fine specimens exist. The large ornamental stoves in the remarkable collection in the castle—or *Schloss*—of Nuremberg are said to be composed of slabs 27 inches by 25, enriched with ornaments and figures in bas-relief of a fine character, the prevailing colours being brown, yellow, and deep copper-green. They bear the date 1657.

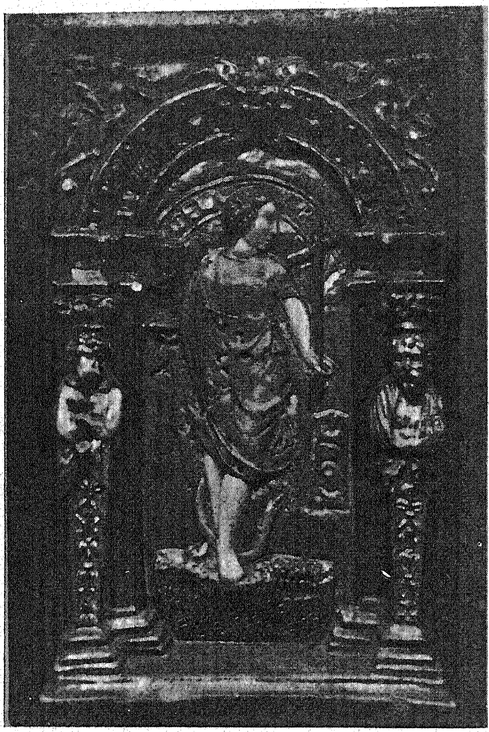


FIG. 96.—German stove-tile. S.K.M.

Linda Villari, in the description of Nürnberg already referred to, says that in the castle the great saloon is lined with . . . . pictures of the early German school, and has a colossal stove decorated in Renaissance style. There is a great fascination about these Nurëmberg stoves. No two are alike; each has its own individuality, but all are immense structures of coloured tiles, covered with designs and bas-reliefs and all sorts of fantastic ornamentation.

The writer adds:—"With these temples of heat rising from floor to ceiling, it must be easy enough to defy a northern winter." (*Leisure Hour*, 1885, p. 831, R.T.S.)

With regard to the ceramic collection in the German National Museum at Nuernberg, Baron C. Bezold, Director, states that there is no special catalogue of these things; but Mr. W. Jackson, A.R.C.Sc., instructor in pottery and porcelain to the Staffordshire County Council, tells me that there is a large collection of German tiles in the Nuernberg Museum, ranging in age from the

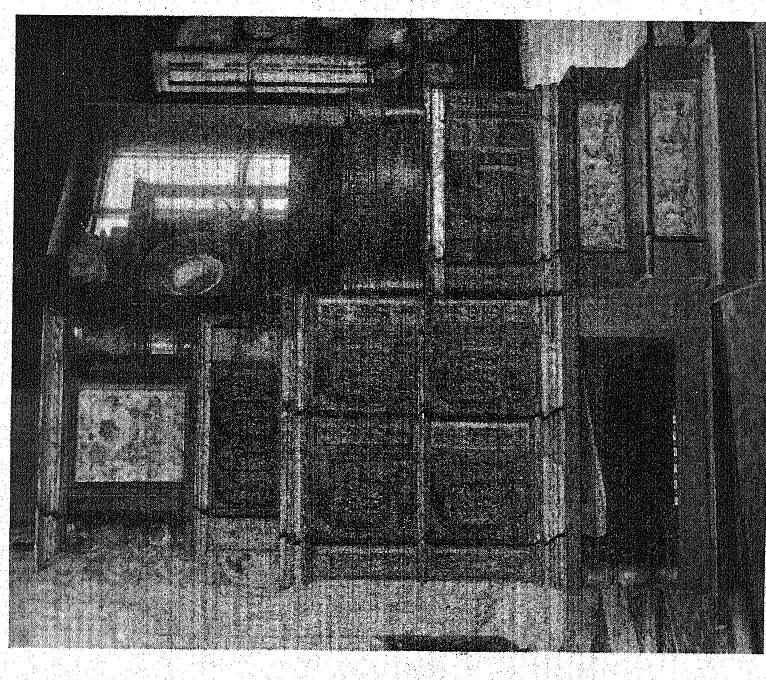


Fig. 97.—German tiled stove in the Victoria and Albert Museum, South Kensington. *(By permission of the Board of Education.)*

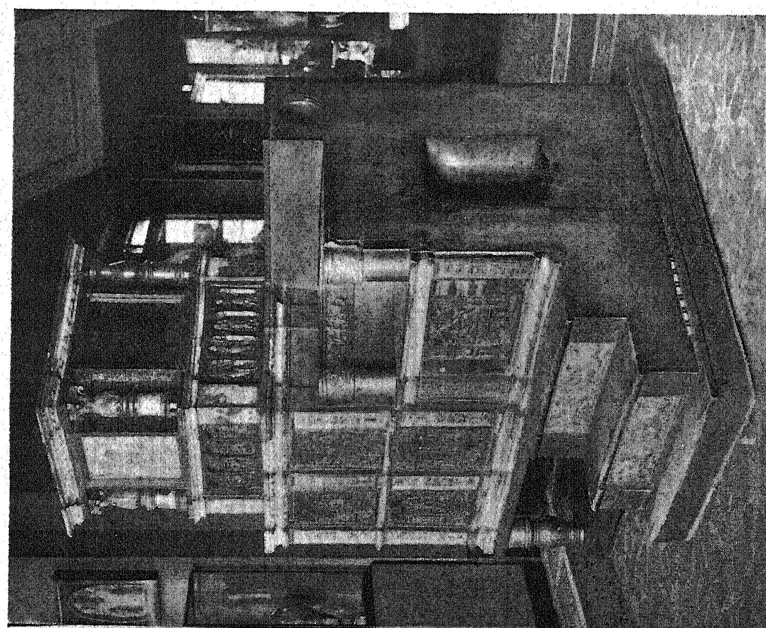


Fig 98.—German tiled stove in the Victoria and Albert Museum, South Kensington.

thirteenth century. In addition, many specimens are to be found in the Rhenish provinces, and in the museums of Stuttgart, Munich, Darmstadt, etc.

The thirteenth-century work, he states, is represented by a large unglazed tile 16 inches by 24 inches, bearing a design which includes the double eagle and the griffin. In the fourteenth and fifteenth centuries heraldic motives are seen in the designs of tiles which are executed in green, yellow, and white; while in the later period leaves, flowers, acorns, and geometric figures are found in the designs, which are carried out in polychrome.

The stove-tiles (*Kacheln*) are a natural development of the wall-tiles, and are decorated in a similar manner, with impressed or relief designs representing heraldic or mythological subjects in polychrome. Eighty-two stove-tiles from Wurzburg, dating from the fifteenth century, and a particularly fine specimen from Kislegg, now in the National Museum, Nuernberg, are said to be of special importance.

The stove-tiles often differ in shape from wall-tiles; instead of having a plane surface, they are often hollowed into semi-cylindrical form, so that each tile forms a small recess. Hence these hollow-shaped tiles, Mr Jackson states, came to be known as "*Schüssel-Kacheln*," *i.e.*, dish-shaped. These are generally small, about six inches or so square, and may have been developed by imitation of the Italian majolica dishes which were used architecturally, fixed in the plaster of walls.

Nuernberg (Nuremberg) was the centre of this manufacture, and the best-known makers are the Hirschvogels, Leopolds, Hans Kraut, and the Klingenschmidts.

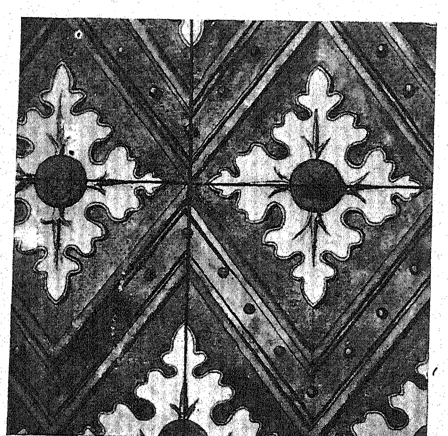


FIG. 99.—Enamelled tile. Nürnberg. (Forrer Coll.)

In 1885, in the windows of St. Sebald's Church at Nürnberg, paintings executed by Hirschvogel were still to be seen. It is also interesting to note that from Nürnberg, in A.D. 1690, the now world-famed Elers Bros. came to Staffordshire, and found at Burslem clays which enabled them to imitate the bright-red wares of Japan. (*Hist. Pottery and Porcelain*, p. 151, Marryat.)

The Nuernberg stove-tile (fig. 96) is supposed to have been made shortly before 1561 A.D.

The complete stoves illustrated (figs. 97 and 98) are two of three in the Ceramic Gallery, V. and A. Museum.

Dr. Forrer exemplifies German tilework of the Renaissance period—

sixteenth century—by several interesting plates. Illustration No. 5 of plate lii. (fig. 99) represents a relief specimen from Nürnberg; it is enamelled with blue, white, and yellow coloured enamels. By the query-note attached (*Hirschvogel?*) there seems some possibility that this is a specimen of that famous pioneer's work.

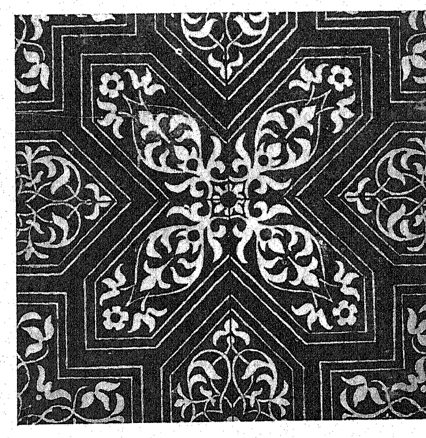


FIG. 100.—Green-glazed relief tile. Köln. (Forrer Coll.)

Fig. 100 represents a specimen of green-glazed relief tilework from Köln a. Rh. (Cologne), and fig. 101 a yellow-glazed relief tile, also from Köln; in each case several tiles are required to complete the figure or pattern.

Tiles used during the second half of the sixteenth century are shown by Dr. Forrer, mostly as relief tiles with heraldic designs, glazed with green glaze only. One tile from Köln, however, has a brown glaze.

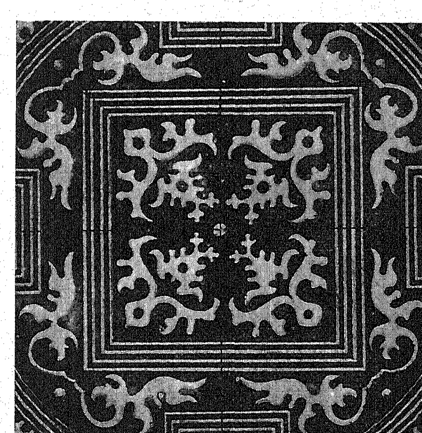


FIG. 101.—Yellow-glazed tile. Köln. (Forrer Coll.)

Tiles of the early seventeenth century he shows as having been principally blue-glazed relief tiles of a yellow-brown body, with geometrical patterns enclosing figures of animals, such as appear in heraldry.

Coming to the eighteenth century, Forrer illustrates German and Bavarian crude imitations of Delft tiles, such as were at this period being largely imported into Germany and also being imitated there.

French Mediæval and Renaissance.—Lacroix states that "From the eleventh and twelfth centuries there existed in France a kind of ceramic art employed especially in the manufacture of varnished pottery tiles." These, probably, are the counterpart, if not indeed the origin, of the monastic pavement tiles already noticed in the English section.

Marryat mentions specimens of such tiles in the Sèvres Museum from the Abbey of Vaulton near Provins, which abbey was founded by Queen Blanche in the thirteenth century. The ground of these tiles is red with ornaments in

yellow, some having a lion, others a cross, represented, and a fleur-de-lis in each angle. Similar tiles are said to have been found in taking up the floor of one of the rooms at Fontainebleau.

Jacquemart writes:—"Until the twelfth century, stones of various colours combined in mosaic had satisfied the requirements of architecture. From this moment a new idea applies itself everywhere at once: bricks of red earth, of varied forms, are substituted for stones, their surface is covered with a thin layer of white clay, in which are incrusted patterns of darker earth, or *vice versâ*; these glazed bricks are thus able to resist the effects of the reiterated steps of the faithful, and replace at little expense the costly mosaics." (*Hist. Cer. Art*, p. 232.)

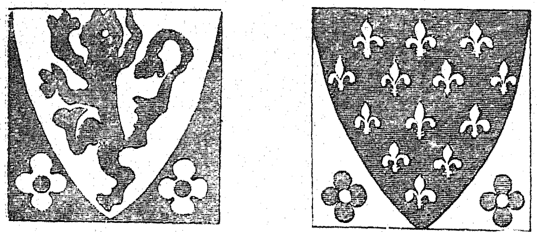


FIG. 102.—Caen tiles. Society of Antiquaries, London. (*After Marryat, by permission of Mr. J. Murray.*)

At Caen, in Normandy, a pavement was found, the separate tiles of which were emblazoned with heraldic bearings. This pavement is supposed to have belonged to a building or convent by William of Normandy, and to have covered a floor measuring 150 feet by 90 feet. The tiles were about 5 inches square, made of baked earth. Eight rows of the tiles running from east to west bore the arms of William's followers, and between these were ornamental compartments of tiles formed into a maze. Of the state of this pavement at the time of the French Revolution, Dr. Ducavel said:—"Notwithstanding these rooms have been used as granaries upwards of four hundred years, neither the damp of the wheat, the turning and shifting of the grain, nor

FIG. 103.—Incrusted tile from Paris. (Forrer Coll.)

FIG. 104.—Incrusted tile from Paris. (Forrer Coll.)

the wooden shoes and spades of the peasants, constantly employed in bringing in and cleansing the wheat, have in the least damaged the floor or worn off the painting from the tiles." (*Pict. Gall. Arts*, p. 183.)

Part of this Caen floor eventually was purchased by Lord Henniker, and presented to the Society of Antiquaries of London. The secretary, W. H. St. John Hope, Esq., F.S.A., tells me that the tiles now only number sixteen, and are only Norman in the sense that they were found in Normandy, their actual date, at the earliest, being the thirteenth century. They have a ground of yellow slip on a body of red clay, and this is irrespective of the field of the shields, which is sometimes yellow and sometimes red.

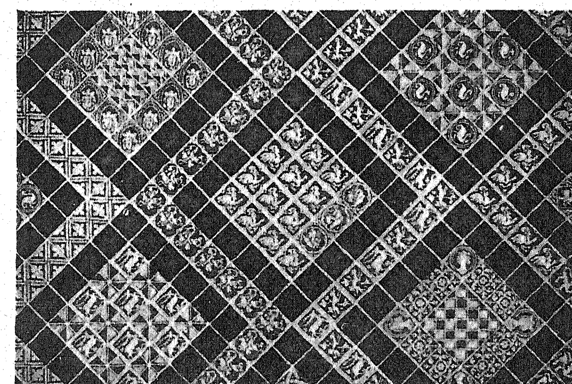


FIG. 105.—Tiled floor of St. Omer. Thirteenth century. (*After Forrer.*)

Dr. Forrer has kindly consented to the reprinting of illustrations of two red and yellow incrusted tiles of the thirteenth or fourteenth century, from Paris, but now in his collection, one a monogram tile and the other ornamental (figs. 103 and 104). He also permits the reproduction of his illustration (after Vacquer) of the very pretty tiled floor of thirteenth century in the Cathedral of St. Omer (fig. 105).

Three other tiles of the incrusted class now in Dijon Museum are illustrated by Dr. Forrer, and described as French white on red incrusted tiles of the fifteenth century. Two of these he kindly permits to be reprinted here (see figs. 106 and 107).

Respecting decorative faience, or enamelled terracotta, its beginning in France may be attributed to Girolamo della Robbia of Firenze, the youngest son of Andrea della Robbia. Born A.D. 1488, in an atmosphere, so to speak, of decorative art, he naturally became a worker in marble, bronze, and clay. Miss Cruttwell assumes that he arrived in Paris about A.D. 1527, and King Francis I. employed him to decorate the famous Château de Madrid in the Bois de Boulogne.

"It thus follows," continues Miss Cruttwell, "directly after the decorations of the Ospedale del Ceppo, on which Girolamo was most likely employed, and it is probable that from them he conceived the further development of a building entirely encrusted with brilliant enamelled earthenware. The palace, unique in the history of architecture . . . . was built at the command of

Francis I., who, set at liberty in 1526, after the treaty of Madrid, returned to his own country full of projects for a life of luxury and pleasure. First, the Palace of Fontainebleau was to be entirely reconstructed, and, not content with that, in the neighbourhood of Paris was to be erected a kind of fairy castle . . . . a palace of faïence, encrusted inside and out with glazed ornaments of brilliant hues and elaborate design. This was the Château de Madrid, situated close to the river in the Bois de Boulogne, to which nearly forty years of Girolamo's life were dedicated, and of which now no vestige remains save a few small fragments of ornament—a curious destiny for the largest of all the Robbia works, a fabric built of a material whose great merit, according to Vasari, was its resistance to time and weather, a durability, as he expresses it, well-nigh eternal." (*Luca and Andrea Della Robbia*, p. , Dent.)

FIG. 106.—Incrusted tiles. Dijon.

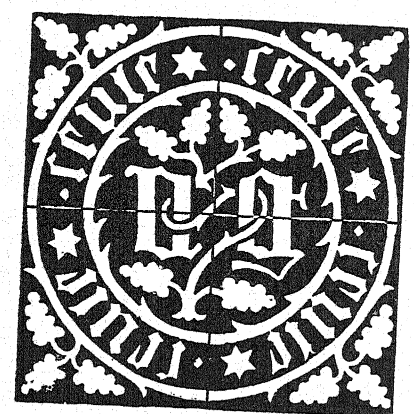


FIG. 107.—Incrusted tiles. Dijon.

Gasnault and Garnier account for this absence of remains by the fact that the Italian faience ornaments and the terra-cotta, upon its destruction in 1792, were sold to a pavior and crushed and turned into cement. (*French Pottery*, p. .)

Two distinct and more or less indigenous developments of the art followed, and in order of time overlapped this manufacture of decorative faience by Girolamo della Robbia in France, namely, that of Abaquesne at Rouen, and that of the more renowned Bernard Palissy of Saintes.

Of the former, Gasnault and Garnier tell us that "As early as 1542 there was at Rouen a manufactory of enamelled tiles, in whose production Italian influence is so conspicuous that no doubt remains as to its origin. From this manufactory originally came the fragments of tiles now in the Museum (South Kensington), and numbered 8490, 8491, 8492—63, 8533—63. These beautiful tiles, evidently made by the process peculiar to the Italian ceramic artists, but essentially French by the style and composition of the ornaments, were formerly in the Château d'Ecouen." (*French Pottery*, p. .)

A certain Masseot Abaquesne is credited with the honour of the first

introduction of this art to Rouen, but after his death the trade in tiles evidently ceased for a long time, and is not mentioned again until the year 1644. With art-potteries busy at Surennes—Girolamo's *atelier*—from A.D. 1530-1566, no stretch of imagination is needed to account for this art-industry at Rouen in 1542 A.D.

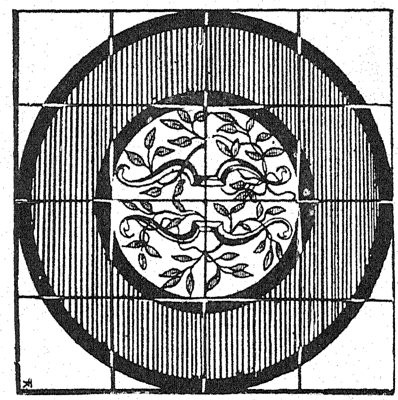


FIG. 108.—Tile-panel from Ecouen, 1542. (Forrer Coll.)

Marryat refers to two remarkable pictures, formed of Rouen tiles, in the possession of H.R.H. Duc d'Aumale, at Orleans House, Twickenham. They are each 5 feet 3 inches by 6 feet 4 inches, and consist of two hundred and thirty-eight tiles enclosed in a frame and fixed to the wall—one representing Mutius Scavola, the other Curtius jumping into the gulf; the colours used are blue, yellow, green, and white—one piece being marked in front *à Rouen 1542*. These picture-panels of tiles are said to have come originally from the Château d'Ecouen, and formed part of the Lenoir Museum.

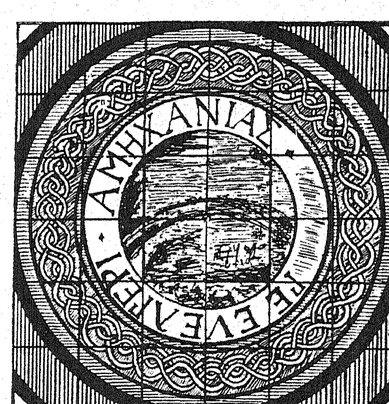


FIG. 109.—Tile-panel from Ecouen, 1542. (Forrer Coll.)

Dr. Forrer very kindly permits the reprinting in this volume of two tile-panels from Ecouen in his collection (see figs. 108 and 109); also of a number of faience tiles (figs. 110, 111, 112, 113).

But, after all, whatever Girolamo did, and whatever Abaquesne did, the greatest name in French mediæval ceramics undoubtedly is that of Bernard Palissy. According to Marryat, he was born at La Chapelle Biron about A.D. 1510, and would thus be seventeen years of age when Girolamo came to Paris. Palissy, it seems, first learned the art of glass-making, including the painting of window glass and its fixing in church windows; and being naturally studious and observant, he acquired considerable knowledge as he went from place to place. In 1539 he married, and then established himself at Saintes, and, becoming possessed of an uncontrollable desire to make enamelled pottery, he worried through a prolonged series of experiments and researches until rewarded with success.

Immediately technical skill had been acquired, his artistic proclivities and his thorough acquaintance with natural history were turned to such good

account that, according to Marryat, Henry II. and the nobles of his court eventually ordered wares of Palissy, and Constable Montmorenci engaged him to decorate his château at Ecouen.

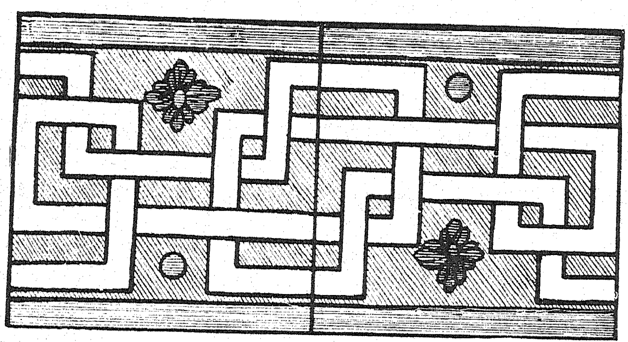


FIG. 110.—Faience tiles of M. Abaquesne from Ecouen. (Forrer Coll.)

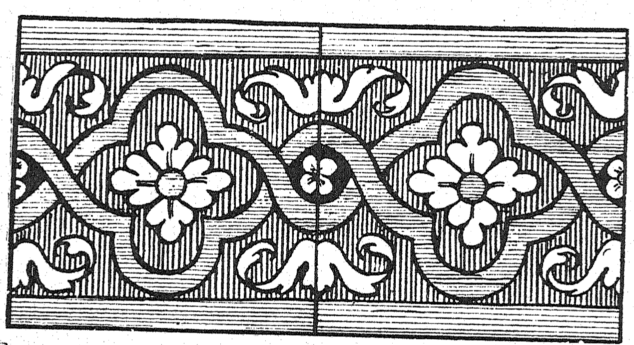


FIG. 111.—Faience tiles of M. Abaquesne from Ecouen. (Forrer Coll.)

FIG. 112.—Faience tile of M. Abaquesne from Ecouen. (Forrer Coll.)

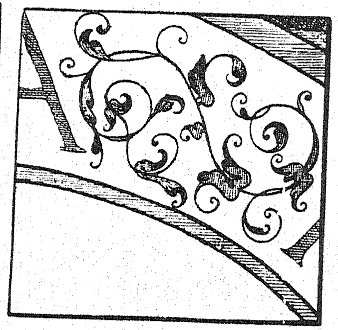


FIG. 113.—Faience tile of M. Abaquesne from Ecouen. (Forrer Coll.)

From this the inference may be drawn, we presume, that both Abaquesne and Palissy were at different times concerned in the ceramic embellishment of this historic dwelling.

Palissy, however, having embraced the principles of the Reformation, suffered persecution, and ultimately was arrested, and his workshop at Saintes destroyed, in the name of religion. With the object of saving him, Catherine de Medici called him to Paris, and gave him a site for a workshop on ground now occupied by the palace of the Tuileries. Here he is said to have produced some of his finest pieces. Marryat pathetically records that in 1588, when nearly eighty years of age, Palissy was again arrested and confined in the Bastille and threatened with death. Henry III. visited him, and, desiring to liberate him, implored Palissy to recant; to these royal entreaties the aged

potter made his famous response, concluding with the French equivalent for "I know how to die." After all, the king would not give up Palissy to his clamouring persecutors, but suffered him to linger in the dungeons of the Bastille, until in 1589 his illustrious life ebbed away.

In describing the peculiarities of Palissy's wares, Marryat remarks that it is characterized by figures, ornaments, and historical or allegorical subjects, represented in relief and coloured, the colours being usually bright, and consisting mostly of yellows, blues, and greys, with occasional use of green, brown, and violet. The white enamel is said to have been not so white as Luca della Robbia's, or even as good as the Nevers enamel, but the enamel was hard.

Another very important characteristic of Palissy's ceramic products is revealed by the chemical analyses published in Brongniart's *Traité des Arts Céramiques*, tom. ii. p. 23, and in *Ceramic Technology*, pp. 17 and 18, namely, the comparative absence of lime-carbonate from the *paste* or "body." This accounts for his being able to burn upon his ware a harder enamel than is found on Italian and Delft wares, and brings Palissy's productions into much closer relationship with Staffordshire earthenwares of the nineteenth century than appears to be the case with any of Palissy's contemporaries who produced coloured glazed faience.

The following comparison of chemical analyses of the respective bodies or pastes will make this clearer:—

	Silica.	Alumina.	Lime.	Iron Oxide.	Carbonic Acid.
Italian maiolica, . .	49·65	15·50	22·40	3·70	8·58
Palissy ware, . . .	67·50	28·51	1·52	2·05	...
English white earthenware,	76·10	20·45	0·75	1·00	...
Delft faience, . . .	49·07	16·19	18·01	2·82	13·09
Persian faience,. . .	48·54	12·05	19·25	3·14	16·72
Rouen faience, . . .	47·96	15·02	20·24	4·07	12·27

(*Ceramic Technology*, pp. 17 and 18, Scott, Greenwood, & Co.)

Palissy's ceramic productions were varied and numerous, consisting of elaborate ewers, basins, dishes, cups, salt-cellars, vases, inkstands, candlesticks, incense-burners, baskets, statuettes, etc., teeming with representations of life and nature; and as many of these articles have been handed down to posterity they give Bernard Palissy, historically, considerable advantage over Girolamo della Robbia of Surennes and Abaquesne of Rouen, whose works have mostly perished by the hand of man and the assaults of time.

With regard to tiles and decorative faience, Marryat writes:—"Tiles for the overlaying of the walls, stoves, and floors of houses [*carreaux de revêtement*] were also made in great perfection by this celebrated artist. . . . The Montmorenci Château at Ecouen . . . . was ornamented with these painted tiles. A great portion of these still exist at Ecouen, where one large room is entirely paved with them, and a considerable number may also be seen in the chapel. . . . They bear much resemblance to Spanish tiles, but the design is wholly French." (*Hist. Pottery and Porcelain*, pp. 98–100, Murray.)

Referring again to the ceramic products of Rouen, Gasnault and Garnier write:—"Faïence, properly so called, coated with opaque white stanniferous enamel, known to the Italians as early as the end of the fifteenth century, and turned by them to such good account, was not known and regularly manufactured in France until the beginning of the seventeenth century." (*French Pottery*, p. .)

Poterat may have had something to do with its introduction at Rouen, although, according to records, there were manufacturers already at work in Rouen before he obtained his patent, and they appear to have opposed his claims.

In A.D. 1789 there are said to have been one hundred and sixty-five manufactories of faience and porcelain in France; of these, sixteen were located at Rouen. That the people of Rouen were skilful and enterprising is well known, for, in addition to earning fame in ceramics, they can claim great distinction in the manufacture of clocks and watches and elaborate and costly cabinet-work, their products realising fabulous prices at sales in this twentieth century.

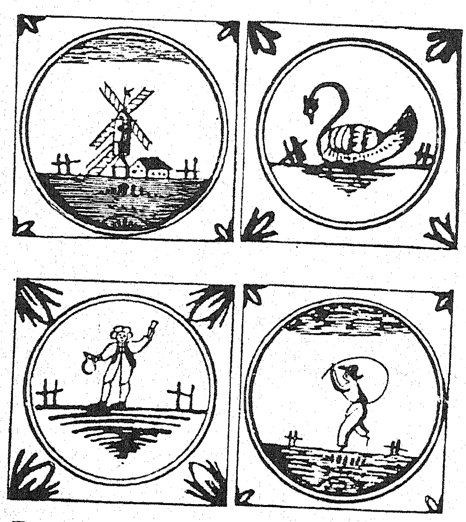


FIG. 114.—Rouen French wall-tiles. Eighteenth century. (Forrer Coll.)

The composition of the body of Rouen ware, as revealed by chemical analysis, has already been given; the composition of the enamels, which resemble those of Delft, M. Deck gives as under:—

Calcine,	44 parts	Mixed together and fused.
Sand,	44 ,,	
Sea-salt,	8 ,,	
Soda,	8 ,,	
Minium,	2 ,,	

The calcine, according to Deck, varied between 3 to 1 and 4 to 1 of lead and tin.

Of these eighteenth-century

French wall-tiles, many of them seem to be almost indistinguishable from Delft tiles. Dr. Forrer kindly permits the reprinting of several of his illustrations of these, which, as with Delft tiles, were sometimes painted with blue and sometimes with manganese-violet colour.

Delft Tiles.—The term "Delft-ware" has unfortunately frequently been used in a general sense to denote all those wares of the seventeenth and eighteenth centuries which were covered with a stanniferous enamel, whether made in Delft or elsewhere. In that sense of the term "Delft-ware" has been made at hundreds of factories in the Netherlands, Germany, France, and England.

Genuine Delft-ware, however, originally was made only in the town of Delft in Holland. It has been asserted that pottery was manufactured there as early as A.D. 1310, but M. Havard, in his *Histoire de la Faïence de Delft*, fixes the date of its earliest manufacture there as being some time between 1596 and 1611. To confirm this supposition, he cites a list of trades permitted to be carried on in the town about the year A.D. 1596, wherein potters are not mentioned, while in a guild-book of 1613 the names of eight potters are given.

Whether the Dutch learned the art of enamelling pottery from their near neighbours in Germany, from some peripatetic or sea-roving Italian, or from Spain, is uncertain. The likelihood of Spanish origination arises from the political relations of Spain and the Netherlands at this time. For, on account of a revolt of the Netherlands from Phillip II., A.D. 1566, the Duke of Alva was sent from Spain in 1567 to suppress it, and in 1573 Haarlem was taken by the Spaniards; great numbers of Spaniards would thus be introduced into Holland.

In the course of the struggle Delft earned the unenviable distinction of being the scene of the assassination of William I., Prince of Orange.

A more circumstantial account of the rise of the ceramic art in Delft, however, has been given in the *Windsor Magazine* (June 1901), in which its origin is attributed to the fact that an Italian potter first settled in Haarlem, and followed his occupation there with success. From Haarlem, early in the seventeenth century, one Hermann Pieters, who possibly had learned the art as an assistant to the Italian, came to Delft and started the manufacture there. By 1620 there were eight factories in Delft, and half a century later there were twenty-eight factories.

Dr. J. W. Glaisher, in a paper read before the Society of Arts on 27th April 1897, said that "vast numbers of tiles were made at Delft, and, as in the case of the other wares, they were of every degree of merit. In most of them the decoration is in blue, but it is often in violet brown. Polychrome tiles are much less common. As a rule, the painting is rough, and in many cases, where the subject is religious, the treatment is somewhat grotesque. . . .

The large plaques made of tiles are characteristic, and date from a very early period. . . . . Many of these plaques are exhibited in the Amsterdam Museum." (*Jour. Soc. Arts*, 11th June 1897.)

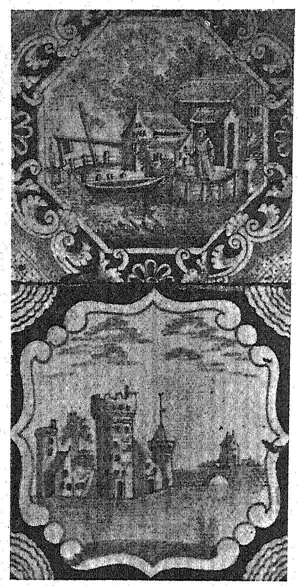
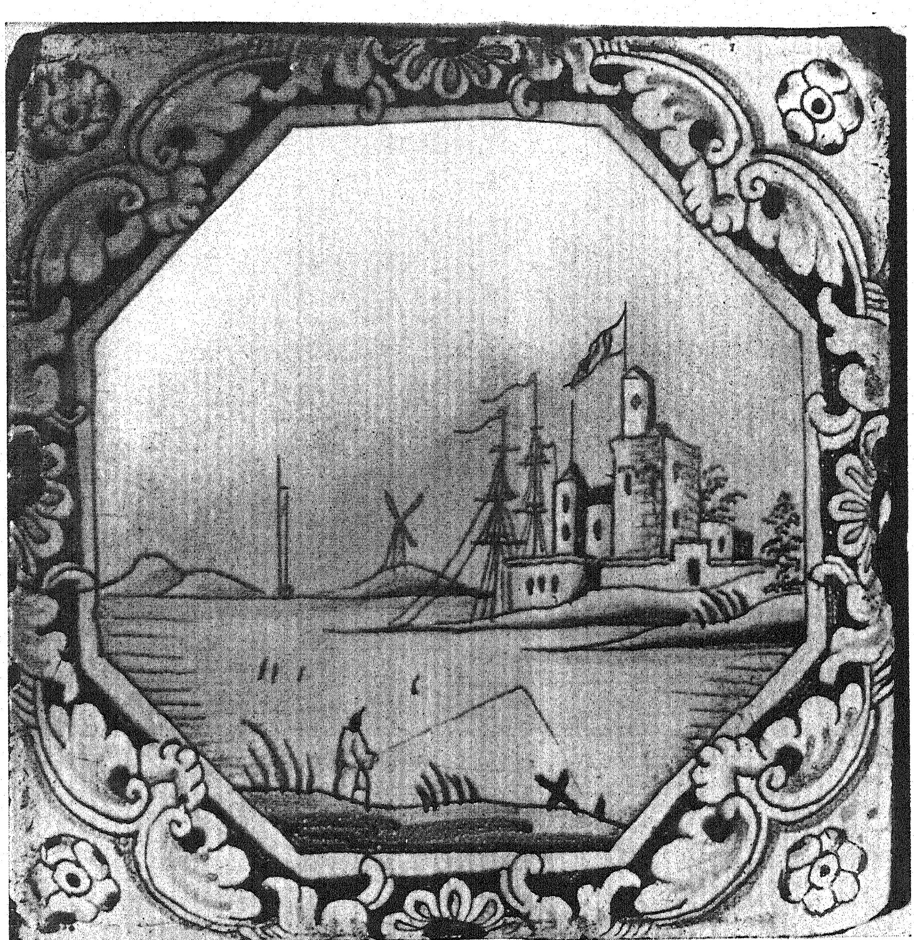


FIG. 115.—Delft tiles. Eighteenth century. (Forrer Coll.)

Dr. Glaisher described the process by which Delft-ware was made as follows, and from this we can infer the method of making Delft tiles:—"The clay was thrown or moulded in the ordinary way and submitted to a first firing. The article was then dipped in a white liquid, the dense matter in which formed a white coating to the body of the earthenware. The painting was effected on this white porous substance. The article was then covered with a transparent glaze and fired again. In the second firing the white coating and the glaze were both fused, the former becoming a white enamel, generally of a milky hue, and the latter a thin layer of glass. Both firings took place in the same kiln, but a higher temperature was required in the second firing to fuse the enamel. . . . . The clay, in its biscuit state, after the first firing, is very absorbent, and when dipped into the liquid rapidly drinks in, so to speak, the water, leaving behind upon the surface a white coating of solid matter. In order to paint upon this spongy substance, which may be compared to blotting-paper, very great dexterity . . . . of the hand is required . . . . the least delay or hesitation on any spot causes too much of the colour to be absorbed there, and spoils the piece. The sharpness of the contours depends upon the limpidity of the colours and the rapidity of execution. . . . . It is clear that painting executed upon so uncongenial a substance cannot be very accurate . . . . but the boldness and vigour imposed by the conditions give to the finished work a special character and charm which is quite its own. . . . . In the case of Delft, the colours are part of the actual ware itself, incorporating with the enamel, and

FIG. 116.—Delft tile. Eighteenth century. Blue monochrome. (Forrer Coll.)



Delft tile. Painted in manganese violet.
(W.N.F. Coll.)

modified and brightened by their contact with the glaze through which they are seen. The body, enamel, colours, and glaze are all fired together at the same high temperature, and form a single work of art, complete in itself, unproducible by any other method, defiant of the attacks of time."

Dr. Glaisher continues:—"The distinguishing point between the wares of Delft and the French stanniferous faïence.—This consists in the fact that the former was covered by a transparent glaze, which is absent in the latter. At first sight it would seem difficult to understand how the glazing was effected without a third firing, as the dipping the painted enamel into a liquid glaze would cause the colours to run. The method is described by Gerrit Paape in his work of 1794, which has been reproduced in French by M. Havard. The workman dips a short rough-haired brush into the liquid, and shakes it violently to get rid of the excess. He then sprinkles the object to be glazed, which he holds in his hand, until it is as white as snow. This process, according to M. Deck, was not followed by the French makers of faïence. The glaze not only has the effect of heightening the colours, but it also protects them from evaporation, and, indeed, to me it seems that it is just this glaze that gives to the best wares of Delft their superiority over those of Rouen and Nevers. . . . It is known that the Italian majolica was covered by a glaze of somewhat similar composition to that used at Delft, and it is almost impossible to resist the conviction that the process must have passed from Italy to Holland. . . . The general superiority of the wares of Delft over those manufactured elsewhere, even by Dutch workmen, must, however, be attributed to the excellence of the mixtures of clays adopted there, which gave to the body of the ware just the right porosity to deposit the proper thickness of enamel, and produced a contraction during firing that was in perfect sympathy with the enamel, so that there were no cracks or other signs of crazing. Gerrit Paape states that the clay employed at Delft was obtained by the mixture of three different clays, viz., the Tournai clay, the Rhine clay, and the Delft clay, combined in the proportions of six, three, and two. He mentions that the Tournai clay was often replaced by that of Brabant, and that the Rhine clay came from the neighbourhood of Leyden, and even of Delft itself. . . ." (*Jour. Soc. Arts*, 11.6.1897, p. .)

The chemical composition of the body or paste of Delft faience is given by Brongniart as follows:—

Silice	49·07
Alumine	16·19
Chaux	18·01
Magnes	0·82
Fer	2·82
Acide carbon. et perte	13·09

And he comments upon it thus:—"Fait effervescence, fond comme le No. 10." (*Traité des Arts Céramiques*, tom. ii. p. 23.)

Respecting the composition of the stanniferous enamel and the glaze, minute details of these and of the mode of preparation are given in the *Jour. Soc. Arts*, 11.6.1897, from which the following abbreviated formulæ have been extracted:—

(A) *Stanniferous Enamel.*

CALCINE.

3 metallic lead } oxidized together in a special furnace.
1 ,, tin }

MASTIC.

500 sand }
60 sea-salt } These were melted together, producing a fragile kind of frit.
30 soda }

ENAMEL OR "WIT" (WHITE).

50 parts of calcine (tin-ash), as above.
65 ,, ,, mastic (silicate of soda frit), as above.
½ ,, ,, smalt.
Small quantity of copper filings.

(B) *The Glaze or "Kwaart."*

36 parts mastic, as above }
42 ,, litharge } well mixed and fused, then finely ground.
4 ,, potash }
7 ,, salt }

With regard to the colours used in decorating these Delft-wares, Glaisher informs us that Gerrit Paape gives the following two formulæ for the blue, viz.:—

Zaffer, 8; smalt, 5; mastic, 4.
Zaffer, 50; sand, 25; potash, 25.

Similarly, for the violet there were two formulæ, one with mastic, another without, namely:—

(*a*) Brownstone, 1; mastic, 1.
(*b*) Brownstone, 1; sand, 2; potash, 2.

The brownstone (*Braunstein*) being one of the ores of manganese. (See *Jour. Soc. Art*, 11th June 1897.)

In a remarkably well-illustrated article by Georg Bröchner upon the notable collection of Delft-ware belonging to J. W. Frohne, Esq., of Copenhagen, in *The Connoisseur*, vol. iii. pp. 209–215, three little technicalities are mentioned that deserve repetition, and may serve to explain the reason of the superior gloss and quality of the best wares:—(1) Contrary to Dr. Glaisher, Bröchner states that "the first burning was the strongest," the ware then being of a pale yellow colour and having a decided ring. (2) Bröchner says, "As a rule a colourless glass powder was dropped on to the decorations, which tended to improve the glaze in the last burning." (3) He writes, "On the more common ware the outlines of the decorations

were generally transferred by rubbing a blacking substance on a pattern with perforated lines. The more artistic decoration was entirely hand-painted."

He adds that "Toward the end of the seventeenth century polychrome decoration came into favour, and was used along with blue, until the whole Delft industry became a thing of the past. The best decoration is red, blue, and gold (after Harvard)—Delft doré." (*Connoisseur*, vol. iii. p. 210.)

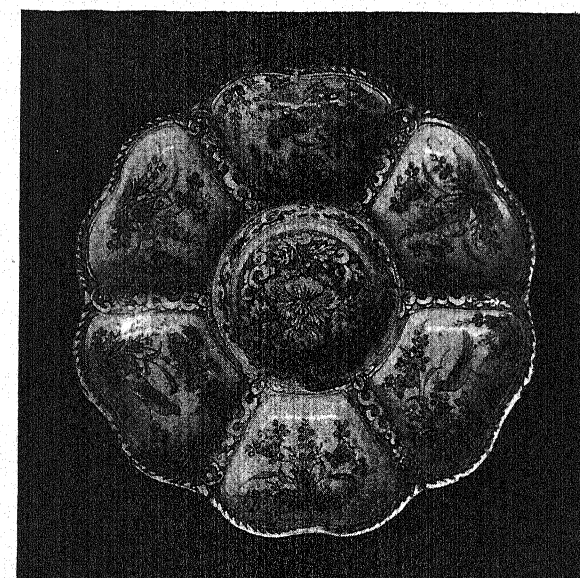


FIG. 117.—Delft dish. (*Connoisseur*, vol. iii. p. 212. *By permission of the proprietors of "The Connoisseur."*)

By the courtesy of the editor of *The Connoisseur*, we are able to illustrate a fine polychrome Delft-tiled stove. In *The Connoisseur* of April 1903 this stove is explained as follows:—"The Canton Schwyz is undoubtedly the most interesting corner of Switzerland, as here are still to be found associations and relics from bygone centuries when the old Swiss nobility sent its sons to serve under the flag of France, forming that royal bodyguard which will be remembered with undying honour in the pages of history. The family of Reding is one of the oldest of the Swiss nobility, and their beautiful country house—plain Maison Reding, as it is called, in true republican fashion—has remained practically untouched since the time it was built in 1640. As can be imagined, it is a perfect treasure-house of rare and beautiful things, and we hope on some future occasion to be able to deal more fully with the subject. The stove, a photograph of which accompanies these notes, bears the date 1640, along with an inscription in Flemish, with the name of the Baron Reding for whom it was expressly made. It is entirely of finely glazed polychrome Delft tiles, representing Biblical subjects and landscapes, no two pictures being alike. As will be seen from the photograph, the shape and design are very fine, in true Renaissance style. A curious feature is the flight of steps at the side, which forms part of it, and terminates in an armchair, large enough to seat one person comfortably. The house contains another stove of

similar make and date, but it is less ornate in character." (*The Connoisseur*, April 1903, p. 270.)

The seventeenth century was "high-water mark" of Dutch ascendancy. Having shaken off the yoke of Spain, their released vigour expended itself in various ways, and, like many who are born in adversity and inured to hardships, the Dutch proved themselves sturdy in after-growth. Following and often usurping the Portuguese in the Far East, they made a great effort at colonization in India, Java, and South Africa; their maritime eminence and energy, and their resourcefulness and activity at home, enabled them to export their manufactures to many foreign countries. Among these, large quantities, both of artistic pottery wares and tiles, were sent out from the plucky little Dutch town, Delft, to Germany, England, and America; indeed, for a time Delft-ware, made in the town of Delft, Holland, was the chief European rival of Chinese ceramists.

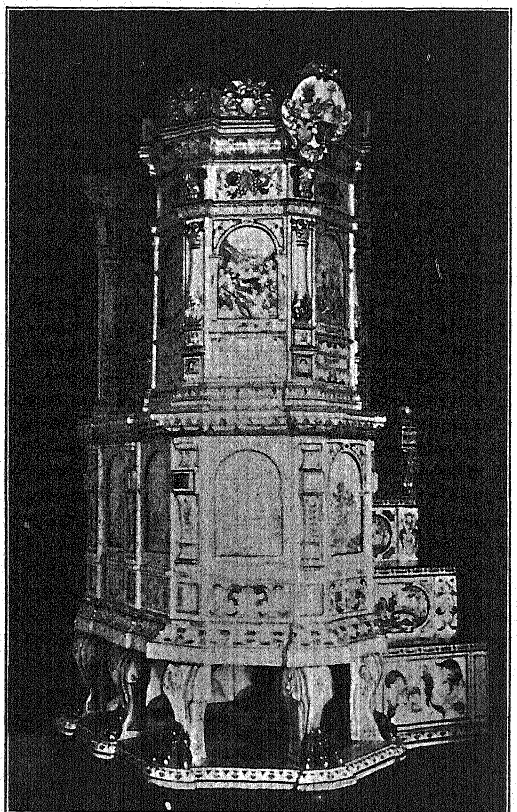
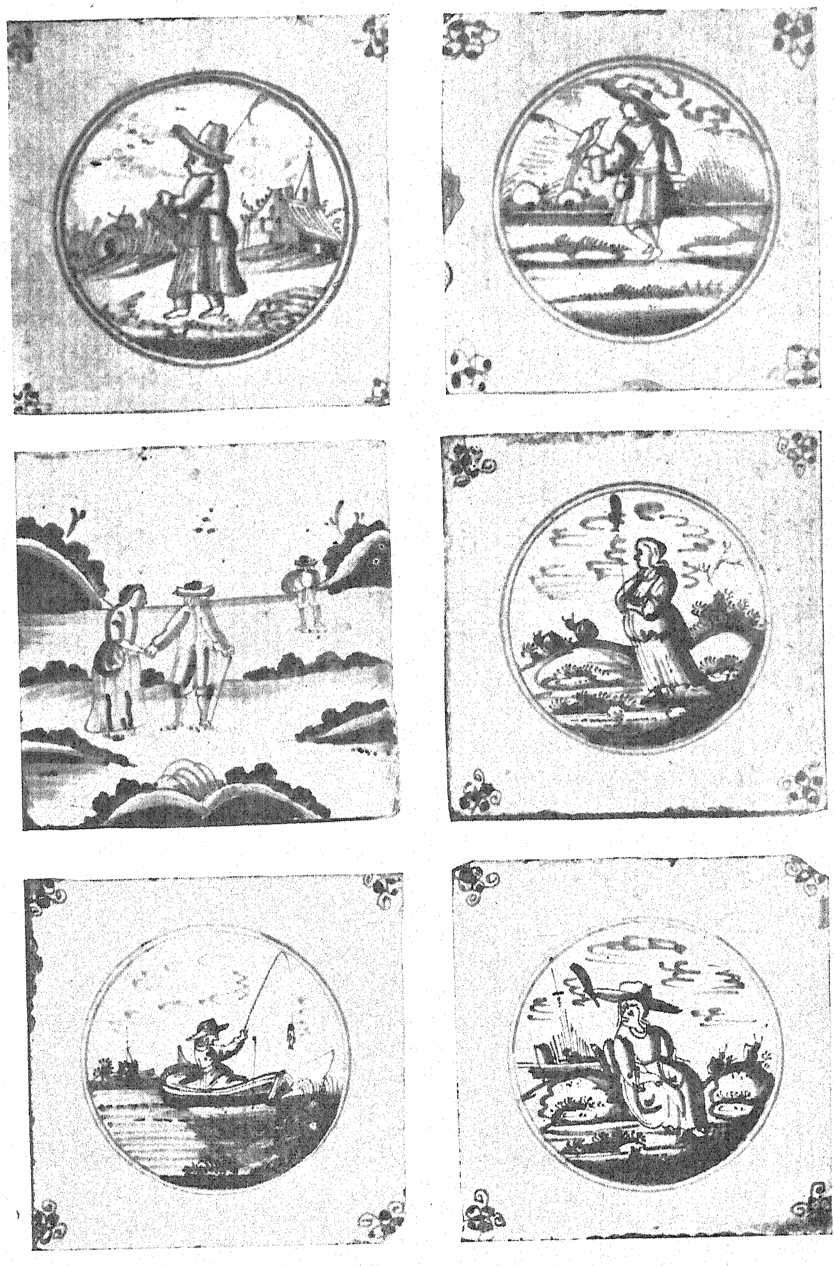


FIG. 118.—Delft-tiled stove. (See *Connoisseur*, April 1903. *By permission of the proprietors.*)

Glazed ornamental Delft tiles were very extensively used for lining fireplaces and walls in the seventeenth and eighteenth centuries, and great numbers are still to be found in English *rariosa* circles and museums, particularly in the Guildhall Museum, London.

With the rise of the ceramic industry in Staffordshire, however, the industry in Delft declined, until in 1850 the last factory is said to have closed. At this juncture, according to the *Windsor Magazine* of June 1901, some time in the seventies, De Heer Joost Thooft, who had retired from active business, and had a taste for Delft-ware, bought "The Porcelain Bottle" pottery (for that was its name), lock, stock, and barrel. He had an idea that a revival of interest in the wares was probable, and in this, events subsequently confirmed



Delft tiles. Painted in blue.
(W.N.F. Coll.)

his foresight. The manufacture was reorganized on more modern lines under the direction of M. Adolf Lecomte. At the death of Mynheer Thooft the control of the business passed into the hands of M. Abel Labouchere. And although increasing business has necessitated many extensions, the old house, to outward appearance, remains the same as when two hundred years ago the founder hung out the sign "De Porceleyne Fles" where it hangs to-day.

CHAPTER III.

RISE OF THE MODERN INDUSTRY IN DECORATIVE TILES.

CONTENTS.—Revival of the use of tiles—English Delft tiles—Herbert Minton—G. Maw—Prosser & Blashfield—Michael Daintry Hollins—L. Arnoux—Coloured glazes—Dust encaustics—British manufacturers—Continental—Persian—Indian—American—Australian—Chinese—Japanese.

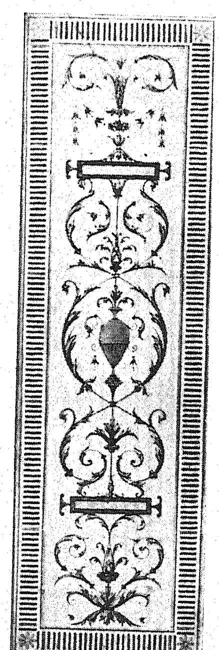


FIG. 119.—Tile panel, by Maw & Co.

ALTHOUGH Babylonia, Assyria, Egypt, Susiana, Persia, India, Spain, and Italy have yielded remarkable examples of the architectural use of enamelled bricks and tiles, yet at no period in the past, so far as we know, has there ever been a time when the use of decorative tiles and faience for interior service and embellishment was really so widespread as at present. These pleasing and hygienic architectural accessories are not now exclusively reserved for the enrichment of palaces and mosques, but are found in some form or other in almost every recently erected public or private building, worthy of the name, in Europe or the United States of America.

This great revival of the use of tiles seems to have originated in England, and there to have created a large special industry, which subsequently extended to many other countries.

In attempting to trace some of the chief incidents of its evolution and development, it seemed advisable to preface these with a short notice of English Delft tiles as a link with the past, notwithstanding that they are in reality, perhaps, unconnected with the present phase of the tile trade.

English Delft Tiles.—The closing of monastic establishments, A.D. 1540–1560, after the fierce contests of Reformation times, coincided remarkably with a cessation of the manufacture of ornamental tiles in Great Britain, where for the succeeding two hundred years the art became practically lost.

In the seventeenth century, however, notwithstanding civil wars, war with the Dutch, the Great Plague, and the Great Fire, a few Dutch potters established themselves in Lambeth. Examples of their products, dating from 1647, or even earlier, are said to be still in existence. On 27th October 1676 letters-patent were granted to a certain Van Hamme, relating to the "Art of makeinge tiles and porcelane and other earthenware after the way practised in Holland."

From Lambeth the industry spread to Fulham, Bristol, and Liverpool; and, according to Mr. W. P. Rix's recent report on the clay industries of Ireland, "Delft"-ware, so called, was made in Belfast two hundred years ago, and in Dublin one hundred and fifty years ago. (*Brick and Pottery Trades Journal*, May 1903.)

Respecting Bristol, in the Museum of Practical Geology, London, there were formerly sixteen "Delft-ware" tiles, painted in blue, with views of Redcliffe Church, said to have been made by Richard Frank at a factory in Redcliffe Backs between 1738 and 1750. (They are now probably in the Victoria and Albert Museum, South Kensington.) In 1777 Frank's business was removed to premises in Water Lane, Bristol, where for many years afterwards it was conducted by Pountney & Co., and was known as Bristol Pottery.

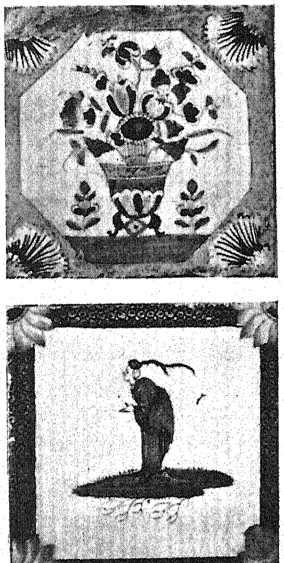


FIG. 120.—Bristol Delft tiles. (F. W. Phillips' Coll.)

Mr. F. W. Phillips, of Hitchin, very kindly permits the illustration of two polychrome hand-painted tiles in his collection, which are believed to be of Bristol manufacture. The body of these tiles is buff-coloured, and is covered with an opaque bluish-white enamel, more glossy, perhaps, than Liverpool Delft tiles. They measure $4\frac{7}{8}$ inches by $4\frac{7}{8}$ inches, are $\frac{1}{4}$-inch thick, and have chamfered edges.

Of one of these Bristol Delft tiles the floral designs at each corner are painted in blue, the border in green, upon which are dots and circles in black, the centre being occupied by a representation of a lady in blue and yellow attire, in a suppliant attitude.

But Liverpool seems to have been the principal British centre of tile manufacture during the latter half of the eighteenth century. Many stanniferous earthenware tiles, in imitation of Delft tiles, must have been made in or near Liverpool about 1756; for on 2nd August 1756, Sadler & Green made an affidavit in connection with their claim to priority in the invention of pottery-printing, in which

they assert that on Tuesday, the 27th July 1756, they printed twelve hundred earthenware tiles.

Coupled with this there is a collateral statement, by Alderman Thomas Shaw and Samuel Gilbody, clay potters, to the effect that they had since burnt these tiles, and that they were considerably neater, and so forth, than hand-painted tiles. No statement is vouchsafed as to who made the tiles, or where they were made. Mr. J. Mayer, in his *History of the Art of Pottery*—chiefly that of Liverpool—certainly refers to Sadler & Green's premises in Harrington Street as a *pottery*, but this seems to be a slight error. Sadler & Green's establishment was an engraving and printing works; if not, and if it were anything more, why did they get Alderman Shaw and Samuel Gilbody to burn the tiles after they had been printed, as per affidavit? Why not burn them at their own works?

FIG. 121.—Liverpool Delft tiles.

Then, again, twelve hundred tiles are rather a large number, and indicate considerable manufacture somewhere, and it would be interesting to inquire where and by whom.

Mayer mentions a potter, named Zachariah Barnes, who had a pottery in the Old Haymarket, and who made a great number of tiles similar to Delft tiles; and relates that "when these tiles were required to be printed, that part of the work was done by Messrs. Sadler & Green." (*Hist. of Pottery*, p. 80.) But this does not account for the tiles printed by Sadler & Green in 1756, for Mayer further explains that Zachariah Barnes was born in 1743, in which case it is improbable he would be a tile manufacturer in 1756.

Unless the twelve hundred tiles in question were obtained in an unfinished state from Lambeth, Bristol, or Belfast—which is unlikely—the natural inference is that Alderman Shaw, who had been a Liverpool Delft-ware manufacturer since about 1716, or Samuel Gilbody aforenamed, had made the tiles and supplied them to Sadler & Green for the purpose of printing, and, when printed, took them away to burn at their own pottery, and to sell.

The name of Josiah Wedgwood will probably occur to most people, at this juncture, as likely to have supplied the twelve hundred tiles, but we are not cognisant of any evidence that he made decorative tiles; at any rate, his historians do not appear to mention such products, and Mr. Cecil Wedgwood assures me he can give no information upon this point.

Josiah Wedgwood certainly sent ware from Burslem to Liverpool, to be

printed by Sadler & Green, between 1762 and 1769; and continued to do so for a considerable time even after the removal to Etruria. (See Jewitt's *Life of Wedgwood*, p. 150.)

But in 1756 Josiah Wedgwood was at Fenton, with Wheildon, and presumably had not then invented, certainly had not perfected, the *Queensware* body; for it was not until 1762 that he presented the now famous caudle service to Queen Charlotte, which gave rise to the name. Black basaltes ware high-relief plaques of large size were made by Josiah Wedgwood, or by Wedgwood & Bentley, of which a valuable specimen, some 15 inches by 10 inches, is in the Museum at Stoke-upon-Trent; but this, too, would probably be long after 1756.

FIG. 122.—Six Liverpool Delft tiles. (F. W. Phillips' Coll.)

The only references to tiles by Josiah Wedgwood that the writer can find are:—(1) A letter from Wedgwood to Bentley, on 23rd November 1772, in which Josiah Wedgwood writes:—"I have a mind to try at some plain tiles, but our people cannot make them cheap enough to sell in any quantities." (Vol. ii. p. 2.)

(2) In 1774 he wrote:—"We do make tablets, etc., for chimney-pieces, but not in imitation of marble. . . . . They are painted in a new species of enamel, upon coloured grounds, from gems, etc."

(3) Tiles are mentioned in one of Flaxman's bills, but not as being manufactured.

Whatever may have been done in the way of tiles, either by Josiah Wedgwood or his Staffordshire contemporaries, it would appear that nothing was known of it by Arnoux in 1877, when he wrote:—"Majolica and Delft tiles, chiefly the last, have been almost exclusively used during the seventeenth and eighteenth centuries, and it is only within the last forty years that we began to make them in earthenware." (*British Manufacturing Industries*, p. 54, Stanford.)

Thus we are driven back to the first hypothesis, that either Alderman Shaw or Samuel Gilbody made tiles of the nature of "Delft" tiles in Liverpool about A.D. 1756.

Liverpool Delft tiles are rather thinner and of harder body perhaps than Dutch Delft tiles, and the colour of the body is of a deeper buff tint, having the appearance of a compound of slender fireclay, plastic clay, and sand. They usually measure about 5 inches square, and are from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch thick, and have chamfered or bevelled edges, either to facilitate manufacture or fitting. The face only is covered with a white opaque enamel, upon which designs are painted or printed according to the period of manufacture; the colours mostly are black, green, and brownish red.

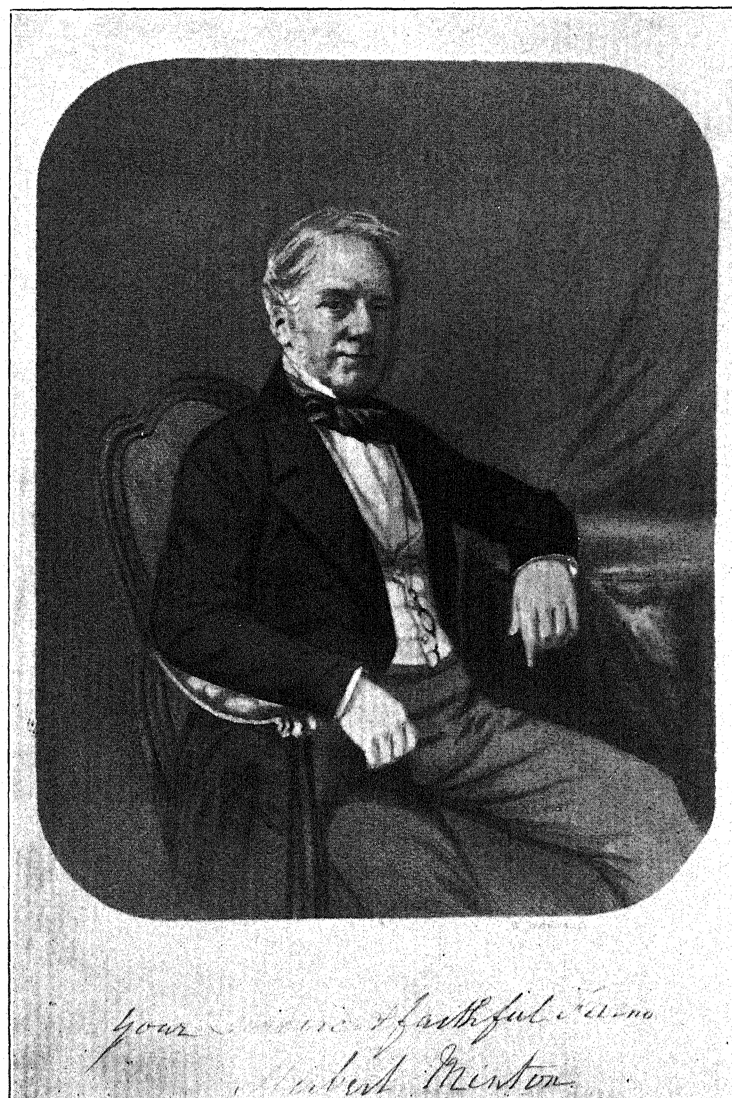
Mr. F. W. Phillips, of Hitchin, who has about fifty of these tiles, has generously supplied several photographs for illustration here. He mentions that the bevel edge tapering from front to back is one of the characteristics of Liverpool tiles.

They are not often marked or signed; indeed, Mr. Phillips writes that he has never seen a signature or mark of any kind on a Liverpool tile. But one of those formerly in the Museum of Practical Geology (London) is signed "J. Sadler, Liverpool." (*Handbook to M. P. Geol.*, p. 157.)

Modern British.—Coming to the nineteenth century: when we contemplate the present extent of the industry it seems incredible that so little of it existed in the first quarter of the nineteenth century. Jewitt states that "in 1828 Herbert Minton first turned his attention to the subject, but was prevented by circumstances from fully developing his plans." (*Cer. Art of Great Britain*, vol. ii. p. 195.) Except for that, all appears to date from 1830, when Samuel Wright, of Shelton, Staffordshire, became possessed of the idea of imitating mediæval encaustic tiles, and eventually secured letters-patent for an invention for making them. The abridgment of the patent reads:—"A manufacture of ornamental tiles, bricks, and quarries for floors, pavements, and other purposes. First, making these articles of fine clays, and firing them until 'semi-vitrified.' Second, ornamenting them in various colours and with various patterns similar to the patterns on carpets, etc., by impressing them with the patterns and filling up the impressions with clay, etc., coloured with metallic oxides. The patterns are impressed by moulding them in moulds of plaster of Paris in metal frames. The articles are reduced to the same thickness by a cutting instrument worked upon a machine, which keeps the article at a true level."

Wright seems to have put his process into practical operation himself first, and to have made some pavements; but the venture was not a commercial success, and, wearying of it, he ultimately disposed of his patent right in part to Herbert Minton, or Minton & Boyle, of Stoke-on-Trent, and in part to George Barr, of Worcester, on certain conditions. Minton pursued this branch of ceramics with indomitable perseverance, resulting, in course of time, in distinguished success, and in the establishment of a world-renowned manufacturing business.

PL. XXII.



Herbert Minton (*d.* 1858).

(*From a print in the Museum, Stoke-upon-Trent, by permission of the Curator, A. J. Caddie, Esq.*)

Jewitt relates that "Mr. Minton commenced the manufacture in a single room . . . . at the earthenware works, and only three men were at first employed. He was much aided in his task by the late Mr. George Leason, a practical potter, who had been brought up under him. . . . . Difficulties had to be encountered, chiefly arising from the irregular contraction of the clays. Sometimes the inlaid parts would at a slight tap at the back of the tile fall out, or the tiles would become stained in the firing; and, in short, all sorts of ill-luck and misadventures were the weekly result. . . . . Repeated failures, however, were only followed by further experiments. Mr. Minton was ever confident that skill and perseverance would in the end prove a success. . . . . In April 1836 Mr. Minton sent to Mr. Josiah Booker, of Liverpool, a plan for tiling his hall, and this gentleman adopted Mr. Minton's suggestions. . . . . In 1837 a hall-pavement was laid in the mansion of Sir John P. Orde, Bart., at Kilmoray. . . . . Tiles were extensively introduced at Trentham Hall, and some of the finest of the early specimens are to be found there." (*Ceramic Art of Great Britain*, p. 198, Virtue & Co.)

The first work of great importance, Jewitt tells us, was the floor of the Temple Church, London. For this, it seems that in 1841 examples of mediæval tiles were procured from the Chapter House, Westminster, and Minton undertook to reproduce the various designs of this ancient pavement in tiles for Temple Church. By great labour he finally completed the work to the satisfaction of those interested.

The only colours made use of about this period, *i.e.*, between 1837 and 1841, appear to have been buff, red, and chocolate; and Minton's highest ambition then was, apparently, to make tiles as good as those of fourteenth and fifteenth century workmanship. What a compliment to mediæval craftsmen!

Thus the pursuit of Wright's invention led Minton on to all that followed in decorative ceramics, and was the beginning of the industry as it now exists.

Mr. George Barr, of Worcester, in conjunction with Mr. Fleming St. John, under the style of F. St. John, G. Barr, & Co., of Palace Row, Worcester, also commenced the manufacture of encaustic tiles by Wright's method, presumably under some agreement with Wright, upon premises that had formerly been occupied by Flight & Barr for the manufacture of porcelain. They issued a catalogue illustrating seventy-seven specimens or designs of their products, which are said to have been excellent patterns and of good colour and material. (See advt., *Gentleman's Magazine*, 1844, and Jewitt's *Ceramic Art of Great Britain*, vol. i. p. 258.)

About 1850 Messrs. George and Arthur Maw purchased this business of St. John, Barr, & Co., and in 1852 they removed the moulds and plant to Benthall, near Broseley, Shropshire, a district noted for the excellence of its potting clays from the time of the Romans, and having the additional advantage of being upon a coalfield. Here Messrs. Maw slowly developed a very

extensive business in the manufacture of high-class ornamental tiles, of which more presently.

Returning a little, chronologically, to pick up another important thread of history, it appears that in 1836 (according to Spon's *Encyclopedia of Manufactures*) a certain Mr. Blashfield made ornamental pavements by combining marble and stone with coloured cements. About this time, too, Messrs. Copeland & Garrett, of Stoke-on-Trent, made ceramic tiles for Blashfield, chiefly of red and black colours. In 1839 Blashfield made an elaborate mosaic floor at Deepdene, by combining several styles of pavement in one design, the mosaic elements being placed face downward on a bench, and then backed by red tiles and cement, forming large slabs that were then reversed, conveyed to the building, and laid in position on the prepared concrete foundations.

The same year Singer, of Vauxhall, made ceramic tesseræ for copying Moorish and Roman work, by squeezing soft clay of various colours from a machine, in thin sheets about 6 inches by ½-inch, and cutting off lengths of about 3 inches of this; these lengths were partly dried and then placed in heaps and cross-cut into small tesseræ, ingenious mechanical contrivances being employed to form curved tesseræ.

On 17th June 1840 Richard Prosser, of Birmingham, obtained a patent for the manufacture of buttons by reducing the material of porcelain to a dry powder and subjecting it to strong pressure between steel dies. The abridgment of the patent specification reads as follows :—" Certain improvements in manufacturing buttons from certain materials, which improvements in manufacturing are applicable in whole or in part to the production of knobs, rings, and other articles from the same materials. These are, first, making the above articles, in which are included bricks and tiles of a clay or clayey earth alone, or partly of clay or a clayey earth and partly flint or feldspar, etc., in a state of powder, by pressure between hard surfaces, either plain or figured, into solid articles, without any water being used, etc., etc."

Prosser sold part of his interest in this patent to the firm of Minton & Boyle, of Stoke-on-Trent, and arrangements were promptly made for putting the matter in operation. Jewitt tells us that "Two workrooms were given up to Mr. John Turley, engineer, who at first placed six button-presses in one, and a large tile-press in the other, and commenced making white glazed tiles (6-inch) and buttons in these works in August 1840." (*Ceramic Art of Great Britain*, vol. ii. p. 202.) About 1841 Blashfield, who, as we have already noticed, had made many experiments and done some practical work in ornamental pavements, saw this process of making buttons at Minton's works, and conceived the idea of extending its application to the manufacture of small tiles and tesseræ.

By "5th September 1842 sixty-two presses were at work"; and Mr. Turley, in his communication to Jewitt, further states that "the demand for

white glazed tiles was soon very great. . . . . On 8th March [1843] the process of making tesseræ was exhibited by Mr. Turley at the Society of Arts, London. March 11th, 1843, the same press and process was exhibited by Mr. Turley at the Marquess of Northampton's soiree as President of the British Association, at which were present Prince Albert, the Duke of Wellington, Sir Robert Peel, a number of bishops, and about thirty foreign princes. The late Prince Consort took so much interest in the process that Mr. Prosser and Mr. Minton decided that a description of the process and a drawing of the press, as then seen at work, should be prepared forthwith and presented to his Highness, which was done, and presented on the 15th of March 1843. After this introduction to the Society of Arts and the British Association, Mr. J. M. Blashfield, Digby Wyatt, and Owen Jones, by their designs and favourable influences, brought the geometrical floor-tile with its many colours, in combination with the encaustic floor-tile, into extensive use in the rebuilding of churches, noblemen's mansions, and other public buildings." (*Ceramic Art of Great Britain*, vol. ii. p. 202.)

Blashfield seems to have been very energetic and influential in securing this public recognition of the work, and devoted money and great personal effort to furthering the use of tessellated pavements; but was obliged for some reason, not particularized, to surrender all interest in the business. Subsequently he established a famous terracotta works at Stamford, where were made the terracotta panels for the Wedgwood Institution at Burslem, the Dulwich College, and other prominent works. Other of Minton's coadjutors who shared the arduous pioneer work were Mr. Michael Daintry Hollins, who joined Mr. Minton in partnership in August 1845; and Mr. Joseph François Léon Arnoux, who appears on the scene about 1849.

From the year 1849 Monsieur Arnoux seems to have been exceedingly persevering in the matter of glaze decoration of tiles and wares of a decorative character, after the manner of the Moors and Italians.

Under his guidance, about 1850 A.D., Messrs. Minton perfected and introduced a new series of opaque enamels, said to be stanniferous, and by them designated majolica. These constituted a striking feature of Minton's exhibits at South Kensington in 1851; and when the permanent South Kensington Museum buildings were erected, between 1857 and 1868, tiles of this character were employed in part for the decoration of the walls. (See Plate XXIII.)

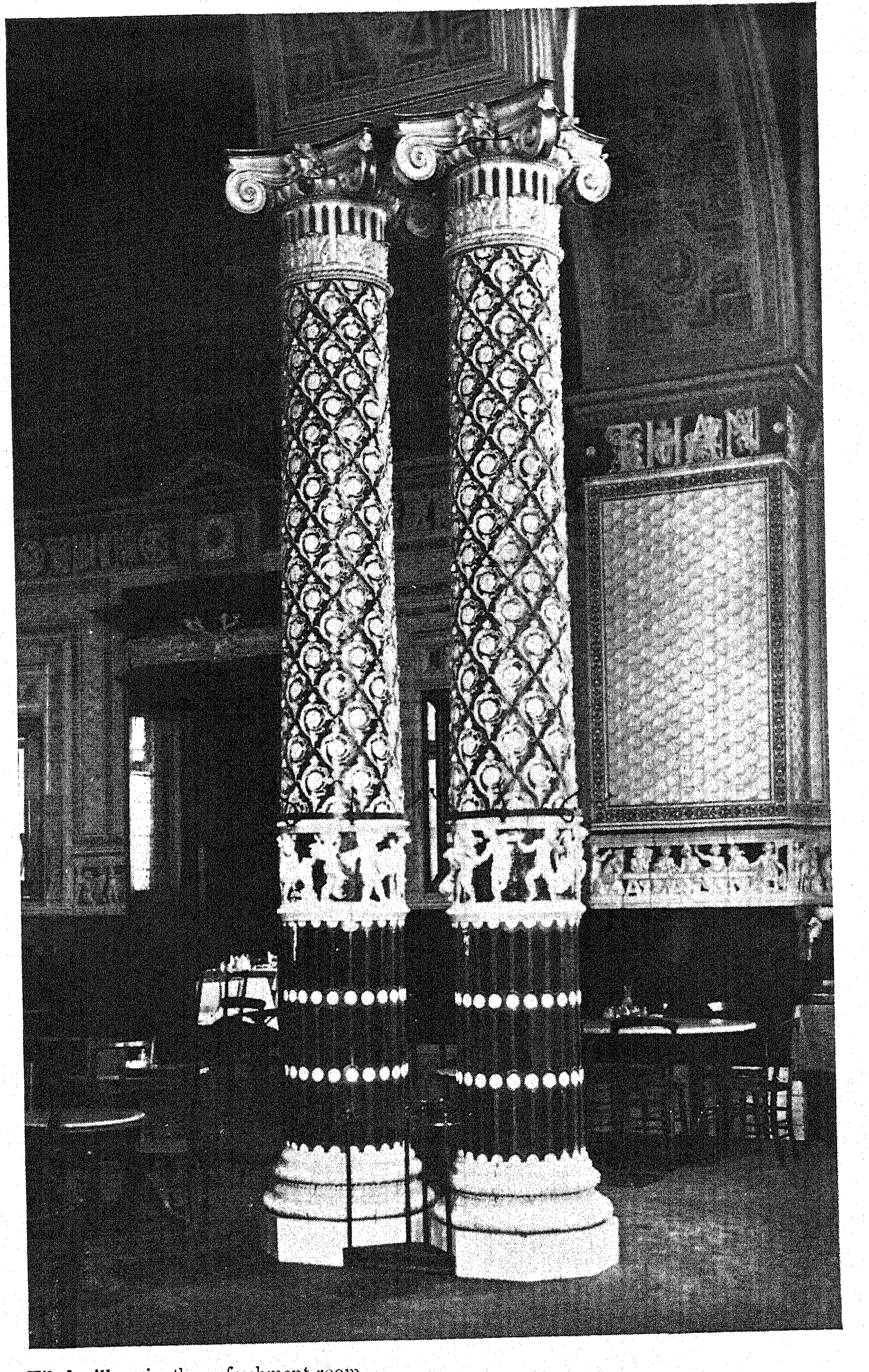
The four pillars, decorated with Minton tiles, in the refreshment-room, S.K.M., of which two are illustrated on Plate XXIII., are typical of the period when they were constructed, viz., 1863 and 1868. Baldry states that "The refreshment-room professes to be entirely a piece of ceramic construction. The lining of the walls, the pillars, and the mouldings and soffits of the arches are made of this material throughout. . . . . The tiles with which the pillars

and parts of the walls are covered are modelled with patterns in low relief, and bands with compositions of figures and inscriptions are added with good effect. The colour is rich but not garish, and it is lightened by the introduction of masses of pure white." (*Modern Mural Decoration*, p. 118, Newnes.)

In the Keramic Gallery (Plate XXXIV.) there are ten somewhat similar columns overlaid with glazed embossed tiles of Minton's manufacture (1868). The staircase leading to the gallery is also decorated with ceramic products.

Writing in 1876 or 1877, M. Arnoux explains that he had "given the name of majolica to that class of ornament whose surface is covered with opaque enamels of a great variety of colours. It is only connected with the Italian or Moorish in this respect, that the opacity of the enamels is produced by the oxide of tin; but as we have not in England the calcareous clay for making the real article, we have been obliged to adapt as well as we could the old processes to the materials at our disposal. At present English majolica is very popular, and without a rival for garden decoration, as it stands exposure to the weather better than ordinary earthenware, besides the impossibility of the latter receiving the opaque enamels without crazing or chipping. Majolica was produced for the first time by Messrs. Minton in 1850, and they have been for many years the only producers of this article." (*British Manufacturing Industries*, p. 51, Stanford.) Whether from difficulties arising out of the nature of fine earthenware bodies, or from want of lasting attractiveness in the earlier opaque majolica enamels used by Messrs. Minton, or yet again for want of adequate interest in the new—or shall we say revived?—material by architects, somehow a quarter of a century elapsed between the modern reintroduction of this style of interior decoration and its recent vast expansion of application. Whatever eulogies are due to the opaque majolicas and to M. Arnoux, let us freely and liberally give; yet they certainly have been almost completely displaced by the more beautiful transparent coloured glazes or art-enamels of the Palissy type, which are now experiencing such world-wide appreciation.

Nevertheless, the decorative tile and faience industry is greatly indebted to M. Arnoux for the perseverance and ability exercised in introducing opaque "majolica" decorative wares, for undoubtedly these opened the way for tiles embellished with transparent coloured glazes, much in the same way that the discoveries of the Astburys, Wheildon, Cookworthy, Chaffers, and Wedgwood contributed to the present state of the general earthenware trade. Nor do we know precisely to what extent we are indebted to M. Arnoux in respect of the use of transparent coloured glazes. Jewitt tells us that it was "in 1851 Della Robbia and Palissy ware were also here commenced"; and M. Solon informs the writer that "transparent glazes were used at Minton's long before the opaque majolica enamels were abandoned," and that he remembers "having seen at Minton's tiles glazed with transparent enamels,



Tiled pillars in the refreshment-room,
South Kensington Museum.
(By permission of the Board of Education.)

certainly dating from the same period as those glazed with stanniferous enamels."

Whether the discoveries in Japan, in respect of glazes, about 1800 A.D. to 1827 A.D., had any reflex influence on Staffordshire products, is, of course, uncertain, but these should not be overlooked as points of historical importance in the matter of glazes. (See *Jour. Soc. Arts*, 26th February 1892, p. 326; and the paragraph on Japanese tiles at the close of this chapter.)

Information, too, may with equal probability have sifted through from India, which about this period was coming more and more under British control, Mooltan being captured in 1849, and the Punjab—one of the principal Indian districts wherein decorative ceramic art is practised—annexed the same year.

Who first recommenced the use of transparent coloured glazes of the Palissy type upon decorative faience in Staffordshire during the last half of the nineteenth century is apparently uncertain. Shaw attributes the introduction of glaze enamelling to Thomas Daniel, but as far as we know he gives no indication of its application to any other than ordinary wares.

Such glazes certainly were in use for other purposes in the eighteenth century, for in 1754 we find that Josiah Wedgwood, after many patient trials, succeeded in producing an admirable green glaze, which contributed largely to the success of Wheildon, with whom he was then in partnership. Indeed, green lead-glazed ware, dated 1691, is known. (See p. 101 of *Handbook to Jermyn Street Museum.*)

About 1780 the so-called "Rockingham" ware was manufactured at Swinton, near Rotherham, Yorkshire, on the estate of the Marquis of Rockingham, the glaze of this ware being coloured by means of the oxides of manganese and iron. (See *Handbook of British Pottery in the Museum of Practical Geology*, *Jermyn Street*, *London*, p. 141.)

Again, recipes for coloured glazes, such as jet glaze, green glaze, yellow glaze, appear in the manuscript books of the writer's grandfather, James Furnival, of Hanley; these recipes would probably be in use about A.D. 1817 to 1840, during part of which period he was a manager for Ridgways, potters, Hanley. And recipes for "Rockingham" glaze, blue glaze, yellow glaze, green glaze, and mazzerine glaze, occur in my father's manuscript books, William Furnival, of Hanley; these recipes would be used at Wilkinson's Pottery, Whitehaven, Cumberland, about 1848–1850, and subsequently at Messrs. Brownfield's, of Cobridge, about 1852, and at Messrs. Copeland's, of Stoke-upon-Trent, about 1860.

Messrs. Josiah Wedgwood & Sons, of Etruria, also revived the manufacture of so-called majolica glazed wares in 1860, and in this material produced dessert and toilet services, and numerous useful and ornamental articles. In 1865 they too were making teapots, coffee-pots, and services including cups,

white inside, of what is known as "Rockingham" ware. (Jewitt's *Life of Wedgwood*, pp. 389–391.)

In 1862 Mr. George Maw, F.G.S., of Benthall, near Broseley, is said "to have first attempted the manufacture of majolica tiles for architectural purposes." (*British Clayworker*, August 1898, p. 136.) By 1871 he had made such advances in the manufacture as to be able to present a fine series of specimens of modern majolica ware, consisting of vases, columns, panels, friezes, medallions, bosses, and many ornamental tiles, to the Museum of Practical Geology, Jermyn Street, London.

These specimens have recently been removed to the Bethnal Green Museum, together with nearly the whole of the pottery and porcelain exhibits formerly shown at Jermyn Street, specimens of exceptional interest going to the Victoria and Albert Museum.

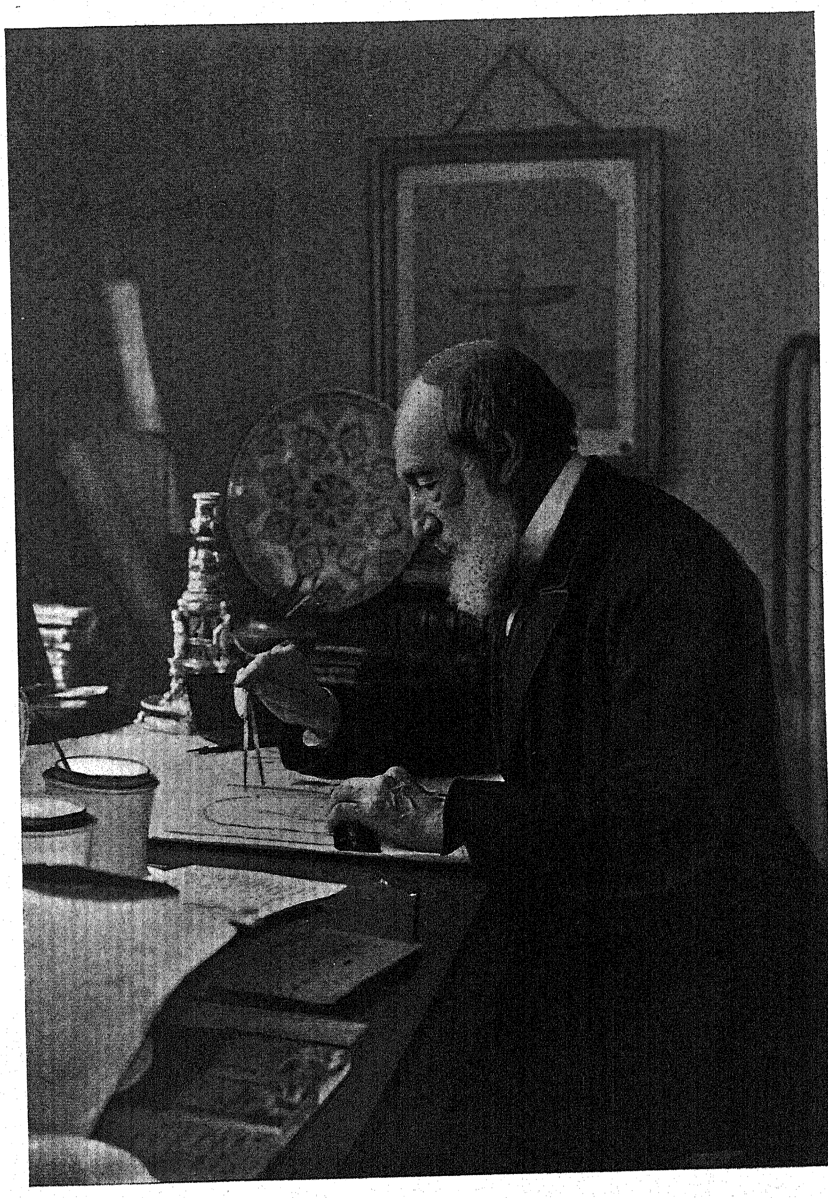
The curator of the Bethnal Green Museum informs me that the glazes of most of these specimens of Maw's early productions in majolica wares are semi-transparent and translucent, but that on some of the tiles the glaze is opaque.

In 1863 another fundamental improvement was patented conjointly by William Boulton and Joseph Worthington, of Burslem. (See patent No. 2176, 3rd September 1863, completed 3rd March 1864.) This was an invention for making figured encaustic tiles by the dust-clay process, and is substantially the method now in vogue. The inlay or figure was formed in perforated plates on the flat surface of the bottom ram or plunger of the dust-tile press, after which operation the plate was removed, and an annular metallic mould raised to form a cavity or mould in which the dust-tile itself was then made upon the already formed design, and all again pressed together.

Omitting minor and secondary matters, this brings us to the contemporary state of the manufacture. The art of the ornamental tilemaker has now spread over the whole of the glazed-pottery-making districts of Europe and America, and has enlisted in its service almost every material, process, and device known to ceramists.

It is due perhaps to all the leading contemporary manufacturers to record here briefly the most noteworthy incidents of their history, and as far as information has been obtainable and at the writer's service for publication this has been attempted; but the notes are unavoidably incomplete, because some manufacturing firms object to publicity in these pages.

Messrs. Minton, Hollins, & Co., of Stoke-upon-Trent, must be granted the premier place as pioneers of the present great revival of the use of ornamental tiles. The leading incidents of the evolution of this branch of ceramic industry by the far-seeing Herbert Minton have already been touched upon, and it has been shown that Minton, Hollins, & Co. are successors to the business he established. Looking once more to Jewitt, we learn that Michael Daintry



Joseph François Léon Arnoux (*d.* 1902).

(*From a photograph kindly lent by M. Solon, of Stoke-upon-Trent.*)

Hollins, nephew of Mrs. Minton, who had been educated for the medical profession, joined Herbert Minton in partnership in August 1845, when, it would appear, the tilemaking department was formed into a distinct concern under the style of Minton, Hollins, & Co., the china and earthenware works continuing under the old style of Herbert Minton & Co., as before.

In 1846 Samuel Barlow Wright, son of the original patentee, was admitted to a share in the tileworks business, which was thereafter styled Minton, Hollins, & Wright. So far the tile business is said to have been conducted at a loss, and only a small amount of business done. Minton, we are told, had sacrificed many thousands of pounds in perfecting the manufacture, and had been extraordinarily liberal in his gifts of tiles. (*Ceramic Art of Great Britain*, vol. ii. p. 203.)

In 1849 Mr. Colin Minton Campbell joined the firm; in 1858 Herbert Minton died, and in 1868 a rearrangement of partnership was effected, by which Michael Daintry Hollins acquired the sole proprietorship of the tile-works, which he continued under the style of Minton, Hollins, & Co. Shortly afterwards Hollins erected an entirely new factory in Stoke-upon-Trent, specially designed for tile manufacture, and here the firm have since conducted their world-renowned business; national and international exhibitions having long been successive scenes of peaceful victory and honour for Messrs. Minton, Hollins, & Co.

Their exhibit for the approaching World's Fair at St. Louis (Mo.), U.S.A., is thus described in the *Staffordshire Sentinel* of 30th March 1904:—

"The principal feature of the exhibit is a large drinking-fountain carried out in faience in a Byzantine style of architecture. The character of the fine piece of potting will be best understood when it is stated that it will stand 7 feet 6 inches in height, has a length of 9 feet 6 inches, and will weigh a couple of tons. It will stand on a rich jasper encaustic floor, made on the original Minton method. The well of the fountain will be laid with turquoise glazed mosaics, the water flowing from a couple of modelled masks set in a wall ebony coloured. The corner pillars, base, and top are treated in greens. A striking feature of the exhibit will assuredly be a framed panel, designed and executed by Mr. Gordon Forsyth, the art director of the firm. The piece of ware, when erected, will occupy a wall-space of 8 feet by 4 feet. The main feature of the decoration is a life-size figure of St. Louis, accoutred for the Crusades, carried out in *cloisonné* glazes standing in a modern faience frame. The colours are very attractive, charming peacock blues and leather brown and white predominating. . . . .

"Another exhibit which arrests attention is an encaustic flooring for a room of moderate proportions. . . . . The floor is in blue and gold, made up of 8-inch tiles, the ornamentation being a free treatment of the Acantha. The brilliant vitreous colours are surpassed by no other firm, and equalled by few.

There are also a number of examples of mosaic-work for walls and floors, and schemes for wall-decoration in enamel tiles. The exhibit will be taken in charge by the British Commission." (*Staffordshire Sentinel*, 30th March 1904.)

Messrs. Maw & Co., of Jackfield, Shropshire, may justly claim the second place for reasons already noted. Upon removing the business from Worcester to Benthall, about 1852, "their first effort was," according to Jewitt, "to thoroughly investigate and experiment upon the clays of the Shropshire coal-field, as well as the plastic material found throughout the kingdom, many of which no one had before attempted to turn to economic account. . . ." "Messrs. Maw," Jewitt declares, "have from the first laid themselves out for applying the very highest art and architectural talents to their manufactures. . . . . In 1861 they commenced the manufacture of very small tesseræ for . . . . pictorial mosaics, and produced for the exhibition of 1862 their well-known mosaic of 'The Seasons' . . . . now in the South Kensington Museum. . . . . Coloured enamels for the surface decoration of majolica tiles next occupied their attention, and after years of experimenting all the colours employed in the ancient tiles of Spain or Italy were successfully reproduced. . . . . A stone chimney-piece enriched with tiles, executed for the International Exhibition of 1862, was their first attempt in the application of enamels and majolica in architectural work. Shortly afterwards the successful decoration of ceilings was carried out in the corridors of the India Office. . . . . Of their works in enamelled terracotta may be mentioned the beautiful staircase executed for Sir D. Marjoribanks, a portion of which was exhibited in the International Exhibition of 1871, and the chimney-pieces manufactured for the board-room of the South Kensington Museum, and the Museum of Science and Art at Edinburgh." (*Ceramic Art of Great Britain*, vol. i. pp. 311–315.)

At length their business increased, until larger works were needed, and about 1883 new works were erected at Jackfield, a few miles from Benthall.

At Chicago, in the great exhibition of 1893, Messrs. Maw & Co.'s exhibit consisted of a most imposing structure of constructional and decorative faience, about 38 feet by 15 feet and some 20 feet high, in the form of a colonnade supporting an entablature. The shafts of the columns were 12 feet high; each contained one painted panel and three modelled panels. The lunettes and spandrils of the entablature were hand-painted in underglaze—a method adopted in all the painted work throughout their Chicago exhibit. The floor-space within was divided by a central screen and side-wings into different sections, which were utilized so as to show specimen pavements, and wall-coverings of tiles, mosaic, and faience, as adapted to the several requirements of churches and public and private buildings. So greatly was this exhibit appreciated in the United States of America that it ultimately found a permanent home in the Columbian Museum, Chicago.

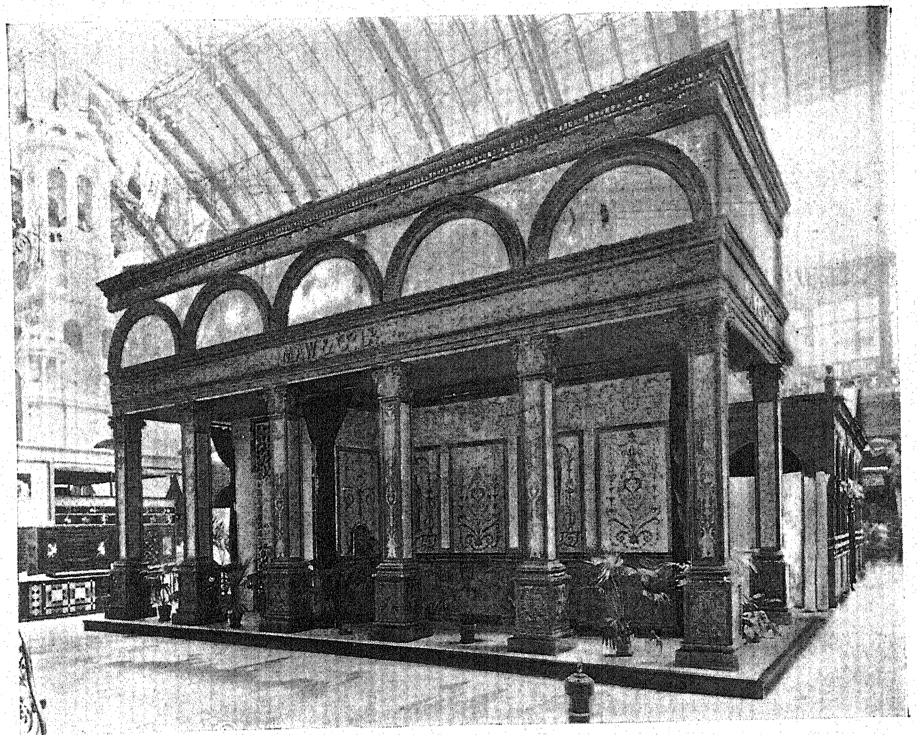


FIG. 123.—View of Maw & Co.'s exhibit at Chicago World's Fair, 1893.

FIG. 124.—View of Maw & Co.'s exhibit at Chicago World's Fair, 1893.

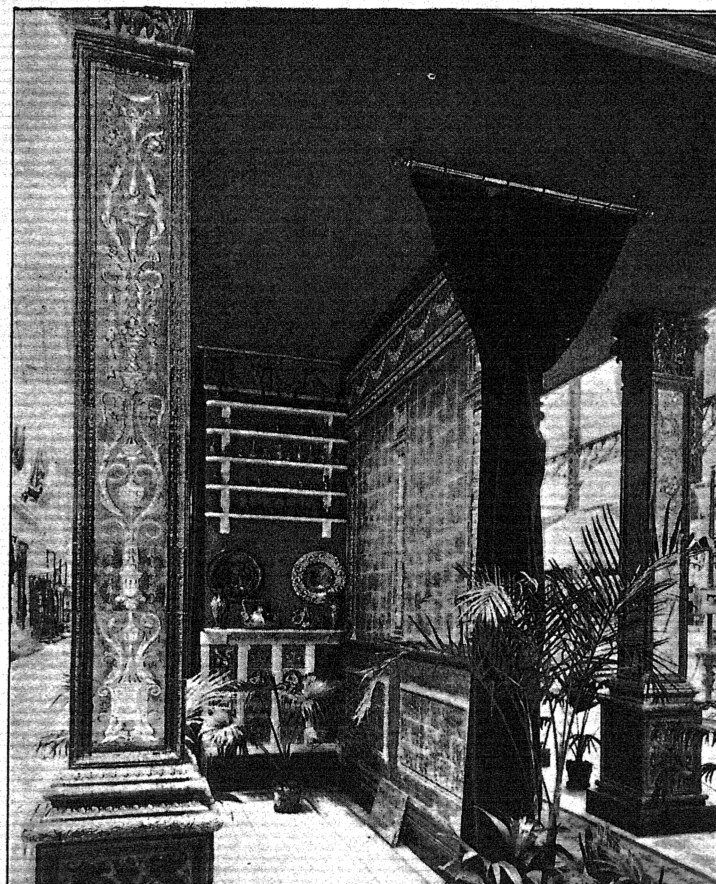


FIG. 125.—Interior view.

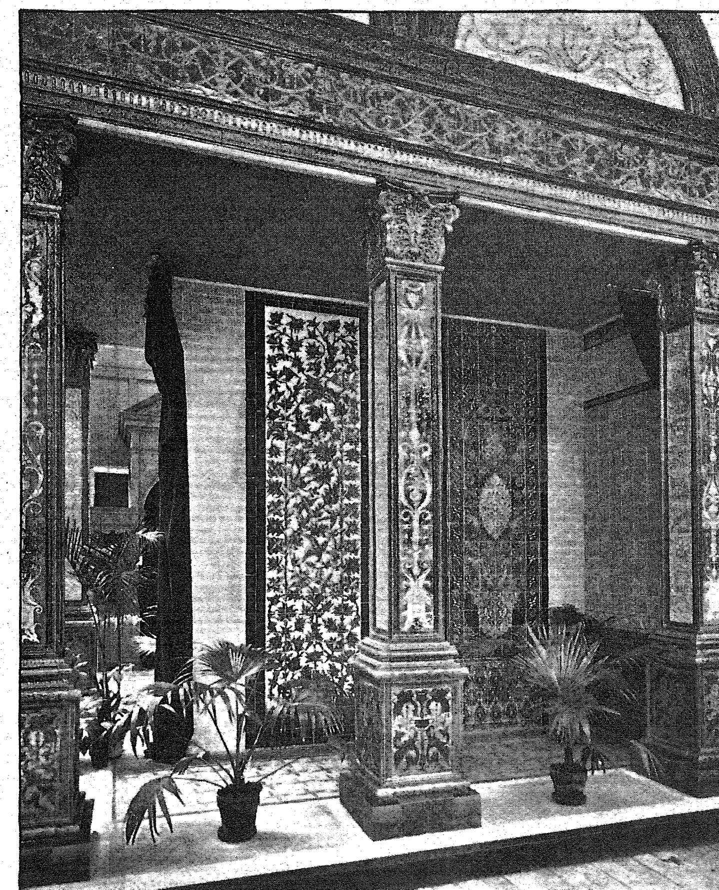


FIG. 126.—Interior view.

Maw & Co.'s exhibit at Chicago World's Fair, 1893.

Messrs. W. T. Copeland & Sons, of Stoke-upon-Trent, should also be mentioned in this connection, although they do not now give much attention to this branch of ceramic art.

As early as 1836 their predecessors, Messrs. Copeland & Garrett, as we have seen, made red and black tiles for Blashfield, who at that time was attempting the construction of ceramic ornamental floors.

Writing in 1878, Jewitt says:—" Messrs. Copeland & Son are large producers of plain and painted and enamelled tiles for internal decoration, and these, from the excellence they have attained in the 'body,' and the skill displayed in design and in ornamentation, have become a speciality of the firm. . . . . One of the most striking and attractive novelties in this kind of mural decoration is that of a continuous design for a whole room, as first attempted by them for Mr. Macfarlane. Of this speciality," Jewitt continues, " I gave the following notice in the *Art Journal* for December 1875:—

". . . . The lining of entire rooms with wall-tiles is, of course, no new thing . . . . but it has been left to Messrs. Copeland to strike out an entirely new idea in the mode of treatment. Mr. Macfarlane, whose art-productions in metal we have often commended in the pages of the *Art Journal*, has recently erected in Glasgow a magnificent mansion. . . . . In several apartments of this mansion . . . . Mr. Macfarlane desired to introduce some new feature. . . . . He therefore wisely consulted Messrs. Copeland, who . . . . prepared a series of designs. . . . . The general design is a terracotta dado of full Indian-red tone of colour, walls of pale celadon tint, and a frieze painted in monochrome, in continuous subjects apposite to the uses of the various rooms, which are thus covered with tiles, in one grand design, from floor to ceiling. The walls between the dado and frieze are covered, as just stated, with celadon tiles placed diagonally, with the joints made just sufficiently apparent to give a geometrical break to the surface, and so remove what otherwise might be a sameness in appearance; while those of the frieze (which are of a pale yellow ground-colour, well adapted for throwing out the figures, and which, when the room is lit up, disappears and gives the effect of a luminous sky to the pictures) are placed horizontally, and their edges fitted with such mathematical precision and nicety that their joints are invisible. The whole of the tiles have a dead or purely fresco surface, and are most perfect for the purpose for which they are intended. . . . . The frieze (3 feet in height) of the billiard-room represents, in four separate groupings on the four sides of the apartment, the sports of the British race: one side being devoted to 'Health' . . . . another to 'Strength' . . . . a third to 'Courage' . . . . and the fourth to 'Fortitude,' in which the central group surrounding the allegorical figure is composed of lifelike portraits of such men as Livingstone, Burton, M'Clintock, Layard, and others. . . . . The frieze of the heating-room of the Turkish baths, which is lined in a precisely similar style to the other, is entirely composed of tropical

plants and flowers, arranged in a masterly and effective manner, and painted, even to the most minute detail, with consummate skill. . . ." (*Ceramic Art of Great Britain*, vol. ii. p. 178, 179.)

Messrs. Copeland & Sons' showroom still has an arched doorway ornamented with decorated panels or slabs throughout its whole circuit, painted by John Cartlidge.

Messrs. T. & R. Boote, of Burslem, have very courteously supplied the following particulars relative to their establishment:—The firm was founded early in 1842 by Messrs. Thomas Latham Boote and Richard Boote, who commenced business at the Central Pottery, Burslem, their original manufacture being Parian statuary and vases, of which a display was made in the first International Exhibition of 1851, and a prize medal awarded. The exhibit attracted, amongst others, the Prince Frederick William of Prussia (afterwards the Emperor Frederick of Germany), who made a purchase. After a few years the Central Pottery was found too small, and the Kilncroft Works was occupied. Ultimately, about the year 1850, the various works on the site of what is now called Waterloo Potteries were purchased and occupied by Messrs. T. & R. Boote. About the same time the manufacture of tiles, which had then been revived by Messrs. Minton, Hollins, & Co., of Stoke-on-Trent, attracted the attention of Messrs. Boote, and they secured the premises on the west side of Waterloo Road, Burslem, and there commenced a business which has since grown to its present dimensions. From time to time changes were made, and between the years 1850 and 1860 the manufacture of white earthenware (called white granite) was undertaken for the American market, the firm suffering very considerably, along with many others, during the American Civil War.

In September 1879 Mr. T. L. Boote retired from the firm, which passed solely into the hands of Mr. Richard Boote, who at that time, and until his death in 1891, was ably assisted in the management by his son Mr. Albert J. T. Boote, and later by his second son Mr. Richard Latham Boote, who, in conjunction with his brother Mr. Charles Edmund Boote, still controls the business, which since 1894 has been conducted as a private limited liability concern. Prize medals were awarded at the London Exhibition of 1861 and the Calcutta Exhibition of 1883, besides awards in connection with several minor displays. The Blackwall Tunnel is one of the public works that have been tiled throughout by this firm.

Messrs. Carter & Co., of Poole, Dorsetshire, also claim to rank among the largest tile and faience manufacturers in England. This firm, Mr. Charles Carter very kindly states, was established in the year 1873, at Poole, in the county of Dorset, by Mr. Jesse Carter. A small works was acquired on the East Quay, which had been built some twelve years previously for the manufacture of tiles, but closed after working a short time, in consequence of the

owner not having sufficient capital. Mr. Jesse Carter had had no previous experience in the business of tilemaking, and consequently many were the mistakes made in the early days of this firm's existence, the needful experience having to be bought, as usual in such cases, at heavy cost. However, by dint of perseverance all difficulties were overcome, and to-day the firm probably make as many tiles as any other firm in the country, besides doing a considerable trade in constructional faience and terracotta.

Mr. Jesse Carter took his sons Charles and Owen into the business in 1881,

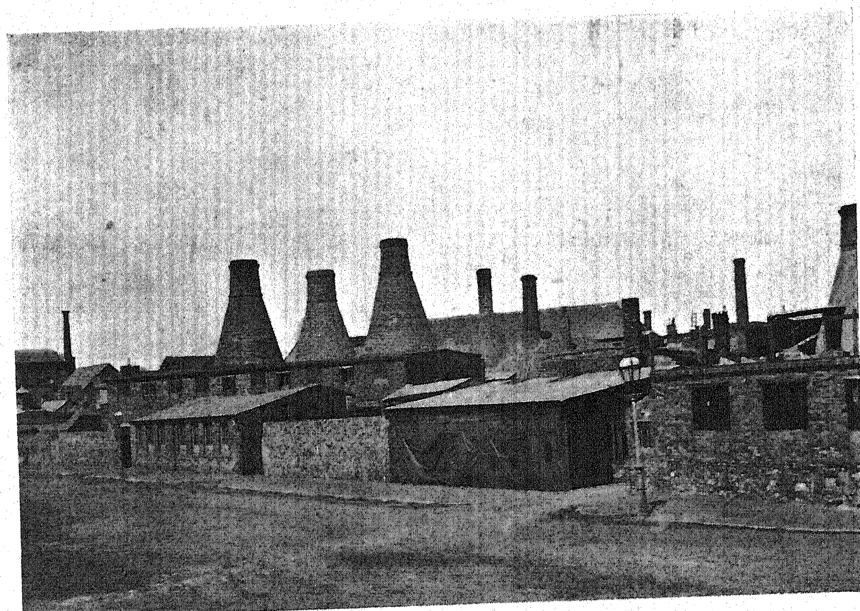


FIG. 127.—Encaustic tileworks, Poole.

and they are now the sole proprietors, Mr. Jesse Carter having retired from partnership about twelve months since (namely, about November 1901).

In 1895 Messrs. Carter purchased the works known as the Architectural Pottery, at Hamworthy, Dorsetshire, where the manufacture of tiles had been commenced in the year 1854 by a Mr. Sanders. This was a very extensive works, but has been considerably enlarged, and further additions are now under consideration. The works at East Quay, Poole, are principally occupied in the manufacture of glazed tiles, terracotta, and faience, whilst those at Hamworthy chiefly produce plain floor-tiles. Messrs. Carter have their own claybeds at Corfe Mullen, where the clay is procured from which their worldfamed red tiles are made. Poole is in the centre of the most celebrated clayfields of the world, and, being a port within easy distance of London and

Southampton, it possesses exceptional facilities for shipment of goods to all parts of the world. Messrs. Carter & Co. employ a large staff of talented designers and modellers. The utility, variety, and excellence of their products will be readily appreciated by reference to the specimen illustrations they have so kindly permitted to appear in this volume; these, of course, merely represent in a meagre way the fertility of design and product this firm are capable of. To really learn what they can supply, their own illustrated sheets must be studied, or a visit paid to both of their works.

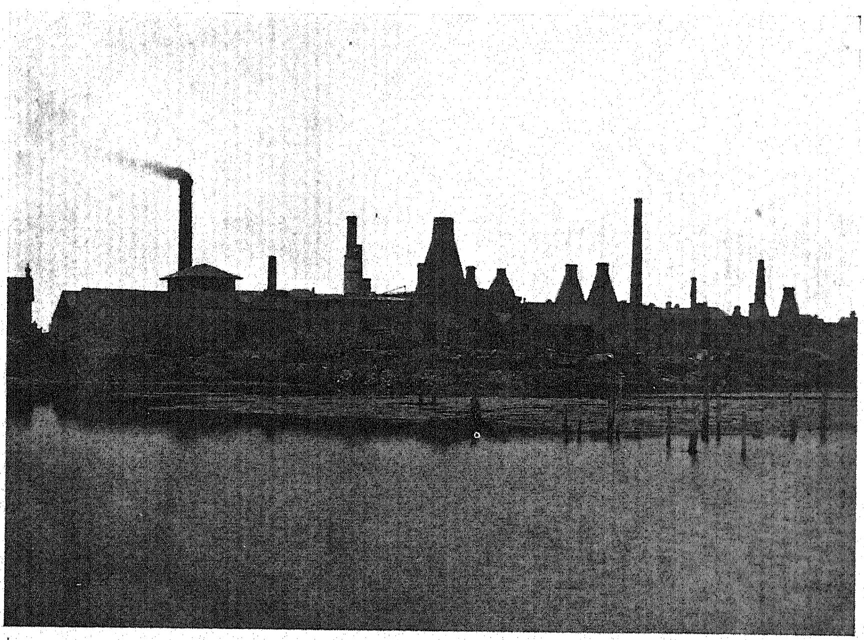
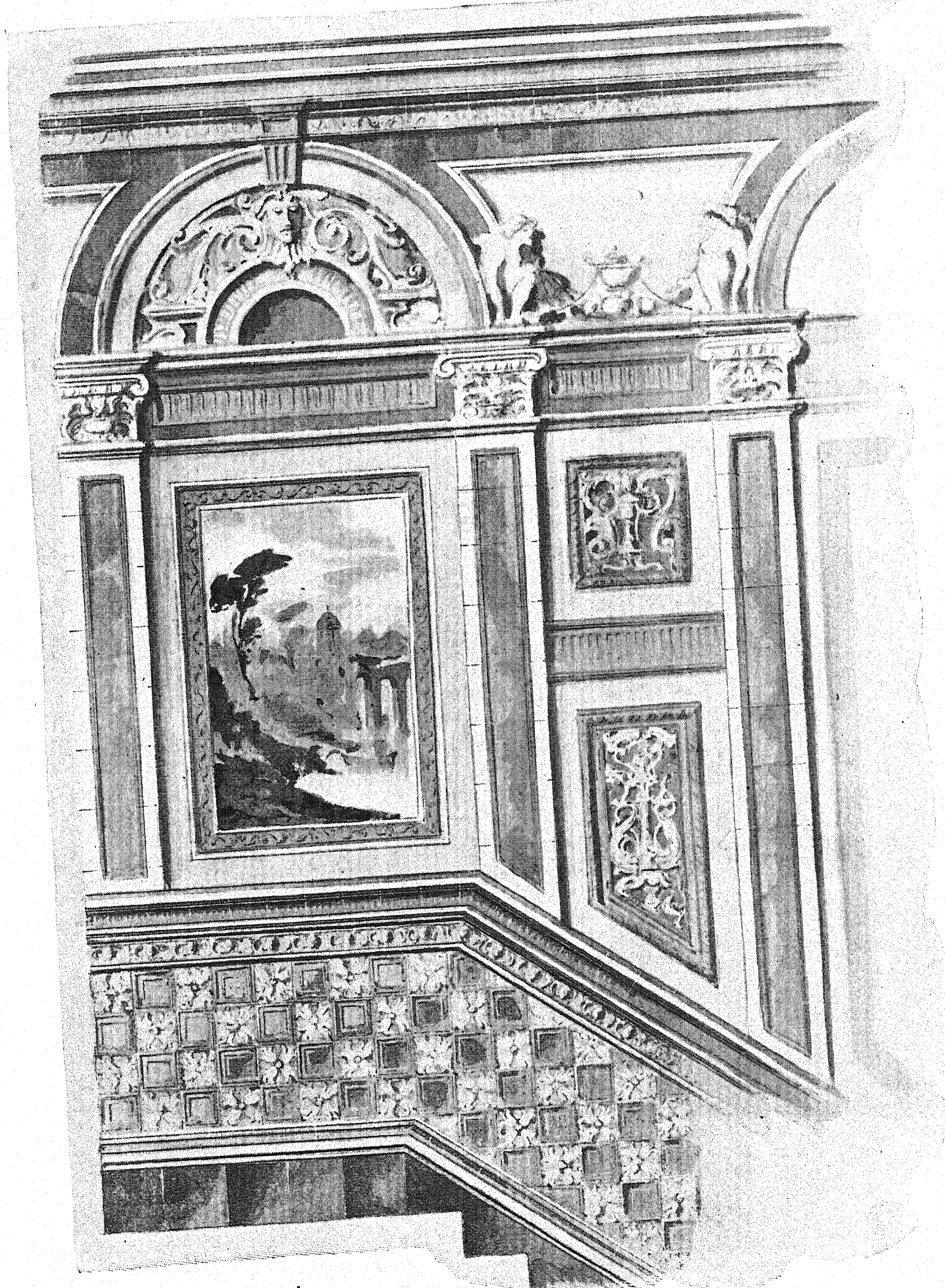


FIG. 128.—Hamworthy Works, Poole, Dorset.

The *Montreal Daily Witness*, of 27th November 1901, made some very complimentary comments upon Messrs. Carter & Co.'s work in connection with the embellishment of the "Grand Trunk" general offices. Mr. Waite, the architect, they say, desired to produce, not so much a building with a roof on it, as a creation at once useful and beautiful. "To-day Mr. Waite was expressing his satisfaction over the perfect realization, by the firm of Carter & Co., Poole, Dorset, England, of his designs for the vestibule. . . . . Then there are panels and friezes for the walls, and the whole work, which occupied Mr. Waite for a long time, was sent to the firm mentioned, with the result that modelling, colouring, and general effects are simply, from an art point of view, entrancing. . . . . Every piece is perfect. The figures have life, not a



Design for treatment of a staircase
by Messrs. Carter & Co., Tile Works, Poole.

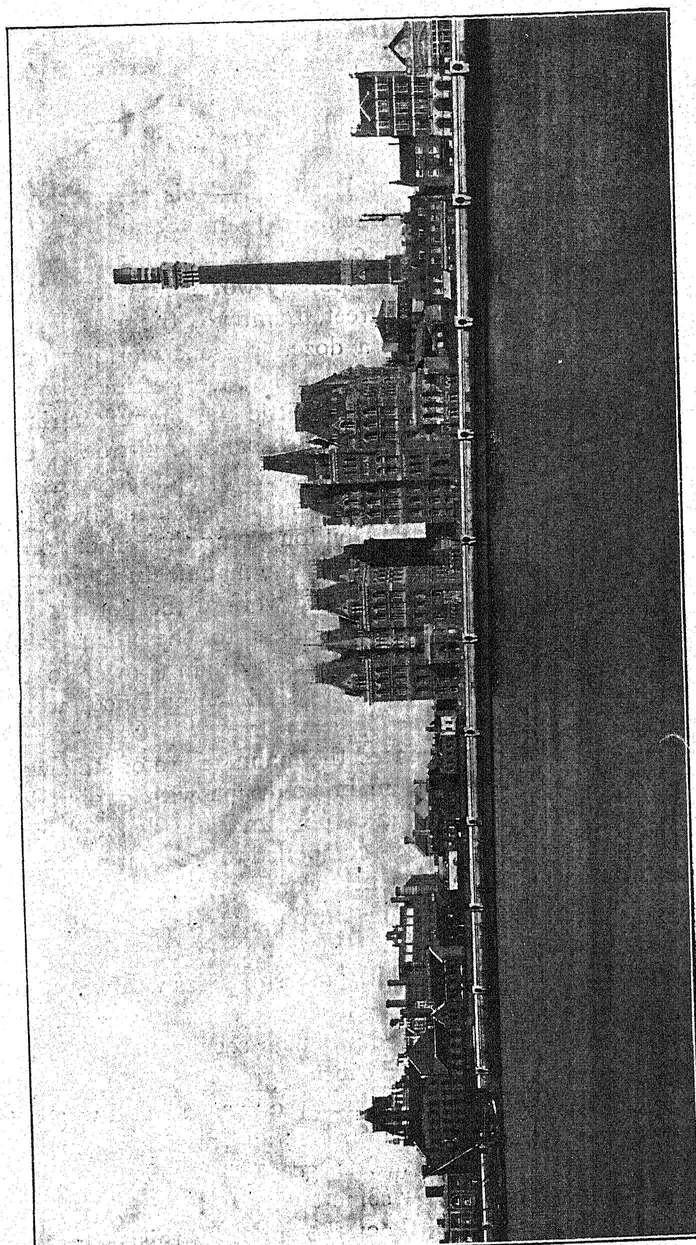


FIG. 129.—View of Messrs. Doulton & Co.'s works on the Albert Embankment, Lambeth, London.

line is missing. And the marvel is—first, that the modelling in the dry should have been so perfect; second, that the colouring, which has all to be done by hand, should be so delicate in every piece . . . . which comprise the design. The shine of the color is splendid. Pale yellows and greens—the æsthetic effects will be perfect. This faïence will be one of the features of the new offices." (*Montreal Daily Witness.*)

Messrs. Doulton & Co., Ltd., of Lambeth.—This great firm date their foundation from the year A.D. 1815, when Mr. John Doulton, after serving his apprenticeship at Fulham Potteries, came to Lambeth, and in conjunction with Mr. J. Watts commenced a small pottery works in Vauxhall Walk. In A.D. 1826 they removed to High Street, Lambeth, the establishment then consisting of no more than about a dozen persons working but one kiln a week. The steadily increasing business, however, ultimately caused the proprietors to extend the works. Little by little the manufacturing premises absorbed the residence, together with its fish-pond, fruit-trees, etc., and now the great factories and studios cover some seven or eight acres of ground. Several of Mr. John Doulton's sons became engaged in the business, Mr. Frederick Doulton and Mr. James D. Doulton giving their attention mainly to the office, while Mr. Henry Doulton entered the manufacturing department.

At the age of fifteen years he commenced work at the potter's wheel. He quickly became very proficient, and doubtless to these early experiences may be attributed his readiness to apply steam driving-power to the wheels, which he did so many years earlier than similar appliances were adopted in other works.

In 1846 Mr. H. Doulton commenced the manufacture of stoneware sewage pipes. The old-fashioned flat-bottom brick drains with gaping joints gave way to the impervious circular ceramic tube, and the demand extended so rapidly that Mr. Doulton found himself compelled to erect larger works. Even these were soon supplemented by branch works at St. Helen's and Rowley Regis; other large works for the same purpose, at Smethwick, Paisley, and Paris, being eventually erected, the present output of drain-pipes from these various works aggregating to about thirty miles of pipes weekly.

About 1867 and onward to 1873 efforts were made to produce artistic wares, and several novel features in the products seem to have hit the public fancy, exhibits at Philadelphia in 1876 causing great interest.

In 1877 Messrs. Doulton & Co. acquired the business and works formerly carried on by Pinder, Bourne, & Co. at Burslem; and, availing themselves of the services of talented designers and artists, greatly enhanced the wares and extended the manufacture, until now some twelve to thirteen hundred operatives are employed there. Not a little of the credit for this success, no doubt, should be attributed to the sterling business qualities and ability of their resident manager, J. C. Bailey, Esq., J.P.

It goes without saying that Messrs. Doulton & Co. were carrying off medals and honours for their useful and artistic products at international exhibitions throughout the world. After the Paris Exhibition of 1878 Mr. Henry Doulton received from the French Government the distinction of a Chevalier of the Legion of Honour. In 1884 the awards gained at the International Health Exhibition alone comprised eleven gold medals, fifteen silver medals, and five bronze medals. In the following year Mr. Henry Doulton was awarded the Albert Medal of the Society of Arts, this medal being presented to Mr. Henry Doulton by H.R.H. the Prince of Wales—now His Imperial Majesty King Edward VII.—on the occasion of a visit to Lambeth Pottery on 21st December 1885.

The height of an operative potter's ambition surely was reached in 1887, when Mr. Henry Doulton was knighted by H.M. the late Queen Victoria.

Upon Sir Henry Doulton's death on 17th November 1897, the business was continued by his son Mr. Henry Lewis Doulton, and on 1st January 1899 the concern was converted into a limited company.

The manufacture of decorative and constructional faience is now chiefly conducted in the High Street and Broad Street Works at Lambeth, and includes fireclay stoves, ornamental glazed ware, mantelpieces, and tiles.

Their "Carrara" stoneware, too, is now used more largely for architectural purposes. The body of this ware is coated and hidden by an opaque crystalline enamel that fires with a slight gloss or "egg-shell" surface; and this absence of a high glaze, combined with a certain delicacy and quietness of colour, commend the material for use in architectural work where glitter is not considered desirable.

The "Carrara" enamel is frequently applied to large works of modelling or sculpture. Presenting a surface which, having been fired at the same intense heat as the substance of the model, is an integral part of the whole mass, the effects of colour are quite permanent, and the sculpture is easily cleansed from the impurities deposited in a town atmosphere.

The same prepared clay that is used for Doulton ware is often fired without a glaze in the terracotta kilns. In the latter case there is naturally no glossy surface, the pieces being protected from the flames and not subjected to the salting process. . . . . Many important statues and groups of figures have been carried out in this material.

For the processes of *Lambeth Faience*, *Crown Lambeth*, and *Impasto* three or more firings for different stages are necessary. The painting, being completed, is first *hardened on*, and then carefully dipped in a liquid glaze, to be finally fired at a high temperature in the glaze kiln.

Bearing some relation to *Impasto* faience, in which the decorations are covered by a glaze, is the method known as *Dry Impasto*, or *Vitreous Fresco*, a very suitable medium for large decorative schemes in churches and public

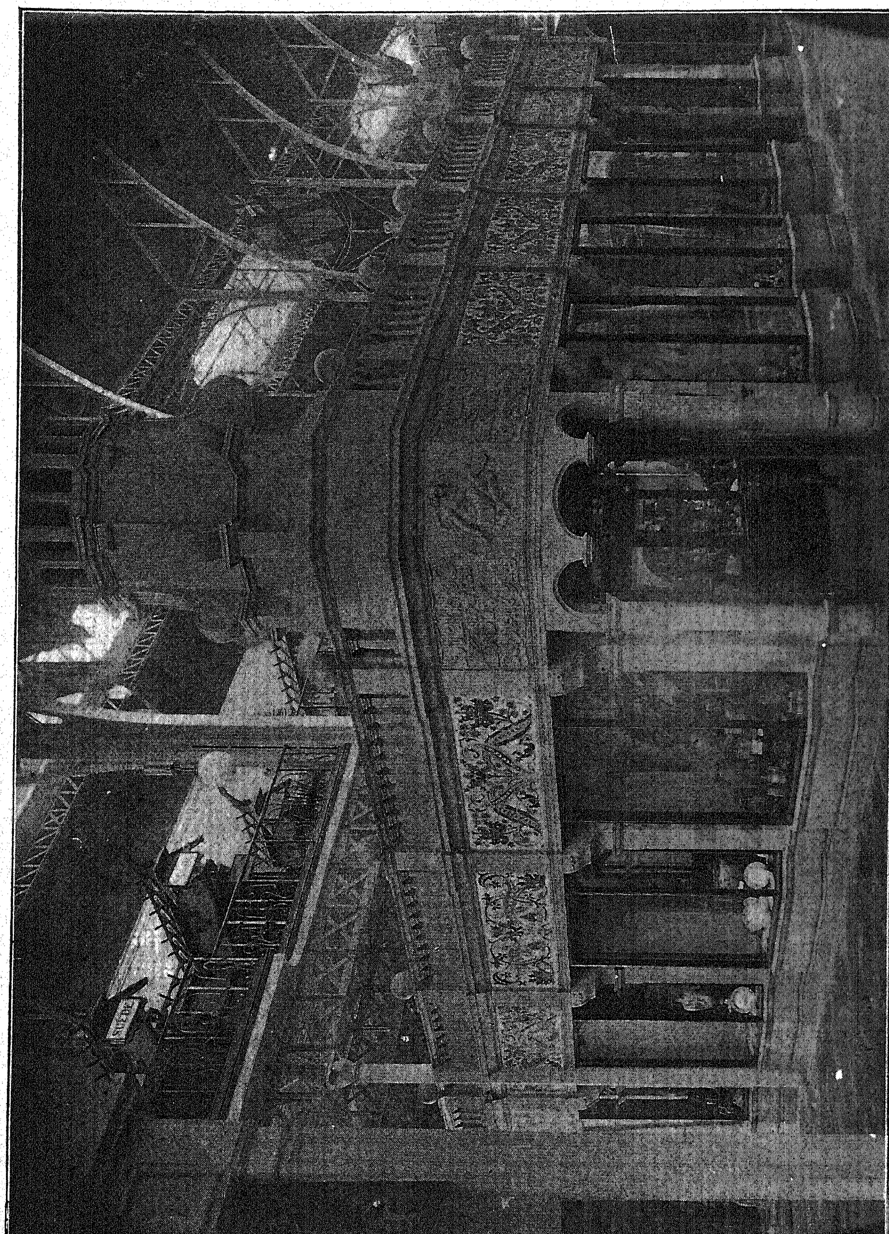


Fig. 130.—Messrs. Doulton & Co.'s pavilion at the Paris Exhibition, 1900.

Vandyck.] [*Photo.*

Sir Henry Doulton (*d.* 1897),
Chevalier of the Legion of Honour.

(*By permission of Messrs. Doulton & Co., Ltd.*)

buildings. The colours are painted on specially prepared terracotta slabs, and are fired with practically no gloss at all, the effect being not unlike fresco painting.

White *Vitreous Fresco* is suitable more for interior decoration, and the development of majolica painting known as *stoneware polychrome*, invented and first used in 1898, offers facilities for permanent exterior decoration. In this method the decorations are fired at the same stoneware fire as the slabs or blocks on which they have been painted, and are thus absolutely permanent. (See *A Description of their Works and Manufactures*, Doulton & Co., Limited, London, 1900.)

J. C. Edwards, of Ruabon, is another well-known firm of ceramic manufacturers, who, amongst their very wide range of products, include tiles, mosaic, faience, glazed, plain, decorated, majolica, encaustic, and embossed, for walls, floors, fireplaces, and the like. "The history of the firm," writes a correspondent of the *British Clayworker*, "indeed reads like a romance. Mr. Edwards came to the work as a novice, and his productions at the onset did not necessitate a bigger staff than a man and two boys. What pluck, perseverance, and untiring energy he must have brought to his business is best evidenced by the fact that at the present time nearly a thousand men are employed, and something like 2,000,000 various articles are turned out per month. . . . . In 1892 he was made High Sheriff of the County of Denbigh, of which he had for long been a magistrate and deputy-lieutenant." Mr. J. C. Edwards died in March 1896, the business being subsequently continued by his sons E. Lloyd Edwards and J. Coster Edwards. (See *British Clayworker*, April 1896.)

It would have been a congenial task to have inserted notices of the history of other large manufacturers, such as Messrs.

Craven, Dunnill, & Co., of Jackfield, Shropshire;
The Campbell Tile Co., of Stoke-on-Trent, Staffordshire;
G. Woolliscroft & Sons, Ltd., Hanley, Staffordshire;
The Malkin Tile Works Co., Burslem, Staffordshire;
The Porcelain Tile Co., Hanley, Staffordshire;
Gibbs & Canning, Glasscote, near Tamworth;
Leeds Fireclay Co., Burmantofts Works, Leeds;
Della Robbia Pottery Co., Birkenhead;
Geo. Swift, Ltd., Binns Road, Liverpool;
Pilkington's Tile and Pottery Co., Clifton Junction, Lancashire;
J. & M. Craig, Kilmarnock, N.B.;
Robert Brown & Sons, Paisley, N.B.;

and several others, but these firms have not supplied the necessary particulars.

Modern Continental.—Only a few of the leading Continental firms having supplied the necessary facts for the purpose of this notice, the following can

only be considered a fragmentary reference to contemporary manufacture in the several countries to be mentioned.

In France the firm of H. Boulenger & Co., of Choisy-le-Roi, stand in the front rank of manufacturers of decorative faience. So far back as 1864 the name of Boulenger appears upon our own British list of patentees in connection with practical potting. Their products cover a wide range in ceramics; for, in addition to manufactures of decorative and architectural elements, the original work of making useful table and toilet earthenwares, and sanitary and electrical wares, is still pursued.

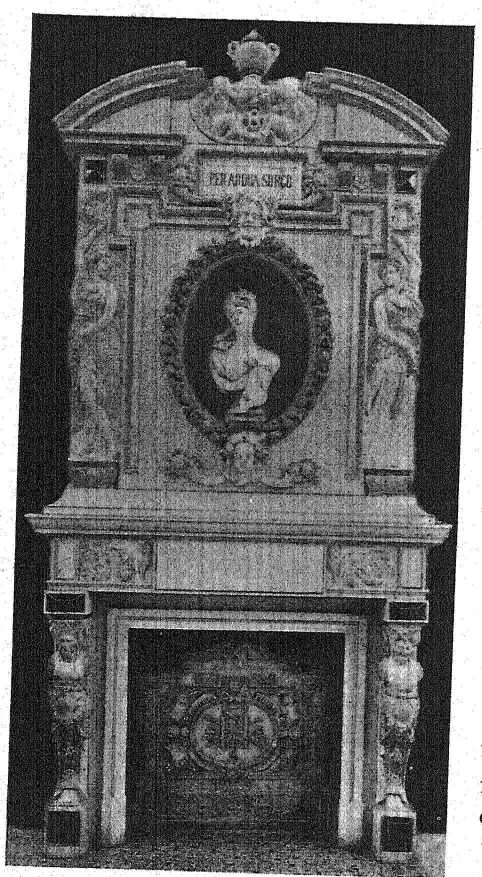


FIG. 131.—Cheminée made by H. Boulanger & Co., exhibited at the Paris Exhibition, 1900.

In 1878 they were awarded a gold medal, and the honour of Chevalier of the Legion of Honour was conferred. Again, in 1889 they were chosen members of the jury of the exhibition. At the Paris Exhibition of 1900 their display was considered one of the marvels of that marvellous conglomeration of the best manufactures of the world

The employees of the firm number some eleven hundred and sixty persons, who are encouraged to associate themselves into various mutually beneficial societies and institutions. The capital is stated to be 3,000,000 francs, and the annual output of decorative tiles alone is said to be 100,000 mètres carrés.

Another large French firm is that of Messrs. Émile Muller & Co., of Ivry-port, near Paris. This was founded in 1854, under the title of the Grande Tuilerie d'Ivry, by Émile Muller, President of the Society of Civil Engineers and Officer of the Legion of Honour, etc. Émile Muller died in 1889, and his son succeeded him in the control of the business. Their well-known replicas of the ancient mural decorations of Susa, recalling the art of the Chaldean Persians, viz., "The Warriors" and "The Lions," which were exhibited at Chicago, Paris, Lyons, and Bruxelles, stand as monuments to the capability of this great firm. The

body and enamels of their monochrome and polychrome stoneware taking a fire of very high temperature, the products are considered specially durable.

Enamelled bricks of all colours, and architectural faience, together with vases, statues, and fireplaces, are comprised in their field of operations.

É. Muller & Co.'s exhibits at the Paris Exhibition of 1900 were distributed over nine distinct classes, in addition to a large share of the constructional and decorative faience used in the exhibition buildings themselves. Their products in class 72 comprised enamelled bricks, monochrome and polychrome enamelled terracotta for constructional purposes; and in class 74, faience fireplaces, stove-tiles, and the like. In 1855, 1867, and 1878 they were awarded medals, and at Paris in 1889 they won two Grands Prix, four medailles d'or, and one bronze medal. Again, in 1900 their exhibition awards included nomination to the grade of Legion d'Honneur, two Grands Prix, four gold medals, and eleven medals to their artists.

Boch Frères, of La Louviere, Belgium, in 1861 established a branch works at Maubeuge, in the extreme north of France, principally for the manufacture of floor-tiles; and here they introduced, in France, the use of dust-tilemaking machines. In 1868 one of their managers, named Simons, is said to have relinquished his position at Maubeuge works, and to have founded a factory on his own behalf at Cateau, which is now, or was until recently, under the management of his sons.

Two other managers of the Boch firm—Sand and Charnoz—commenced works at Feignes and Paroy le Monial respectively.

In 1882 M. Van Overstraten de Smet is said to have established his now famous factory at Canteleu Lille.

Utzschneider & Co., of Digoin and Vitry-le-François, France, who also have extensive works in Germany, produce excellent tiles and faience of all the usual varieties.

A. Bigot & Co., of Paris, appear to pay special attention to stoneware polychrome products, or *grès flamme*.

The Compagnie Général des Céramique de Marseille advertise themselves as manufacturers of glazed decorative tiles and mosaics, together with numerous other builders' ceramic requirements. The works seem to be an old foundation, for by 1874 they secured a gold medal at Marseille, and claim quite a list of medals and honours since.

Fourmaintraux-Courquin & Fils, of Desvres (Pas-de-Calais), also advertise themselves as manufacturers of artistic tin-enamelled faience, decorative tiles and panels, and friezes for interior and exterior purposes.

Then there is the Golfe Juan Pottery near Cannes, in the south of France, where a speciality in form of lustred ware is made. It seems that M. Massier, the proprietor of this works, devoted years of labour and considerable treasure in endeavouring to rival the old Persian lustred products, and

ultimately achieved such success that he ventured to present specimens of his wares to Her late Majesty Queen Victoria. The designs and colour-tones are said to be mostly done by M. Lucien Lévy, the principal tones of colour being blends of purple, green, gold, and red. (See *British Clayworker*, Supplement, April 1896.)

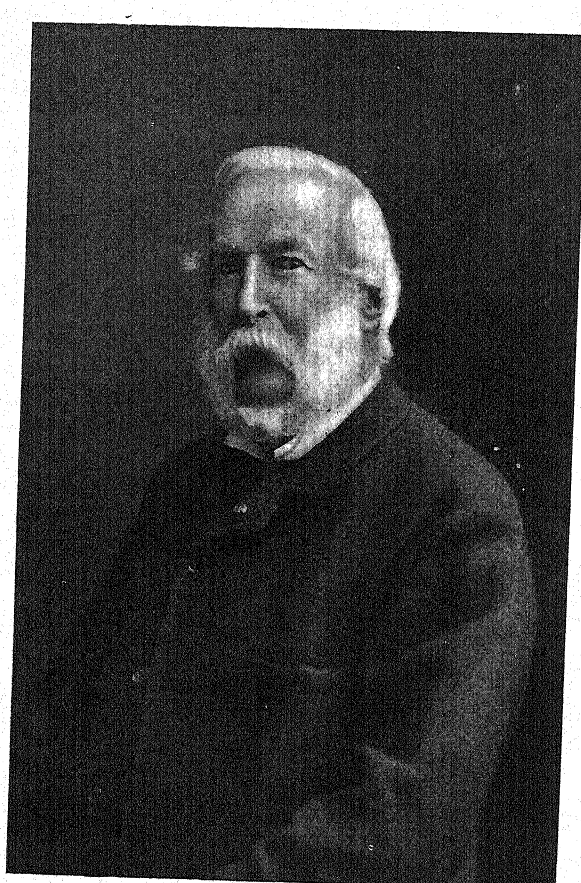


FIG. 132.—Victor Boch.

Other French manufacturers that may be mentioned are Messrs

- Polakowski & Cie., of Roumazieres (Charente), makers of architectural enamelled faience and Palissy ware;
- Huart Frères, of Longwy (Meurthe et Moselle), who, in addition to table wares, manufacture *revêtements céramiques*;
- Soc. Produits Céramique, of Maubeuge (Nord), who confine their manufacture to plain and incrusted floor-tiles;
- Groze, Ailland, & Cie., Viviers (Ardèche);
- Pierre Perret, Vallauris (Alpes Maritimes);
- Fenal Frères, Peronne (Meurthe et Moselle);
- Geoffroy & Cie., Faïencerie de Gien (Loiret);

and many works in Marseille, Aubagne (Bouches du Rhone), in Oise, and in Pas-de-Calais.

In Belgium one of the most important manufacturing firms are Boch Frères, of Keramis, La Louvière (Hainaut). This large establishment was founded in 1841 by MM. Eugène and Victor Boch and Baron J. B. Nothomb. The site of the works was purchased on 18th March 1841, the first stone laid 1st August 1841, and the first kiln set in on 1st August 1844, the erection and subsequent direction of the works devolving principally on M. Victor

Boch. In 1881 he retired from the active management, and was succeeded by M. Charles Toch, civil engineer. The principal products of the firm are earthenwares, similar to those so largely made in North Staffordshire for table and toilet purposes; but they have also developed a special business in imitation of Persian, Rhodian, and Delft wares.

Lastly, during the last fifteen or twenty years decorative tiles and faience, in multitudinous variety of form, design, and colour, have been added to their manufactures. They have a branch works at Maubeuge, just over the frontier,

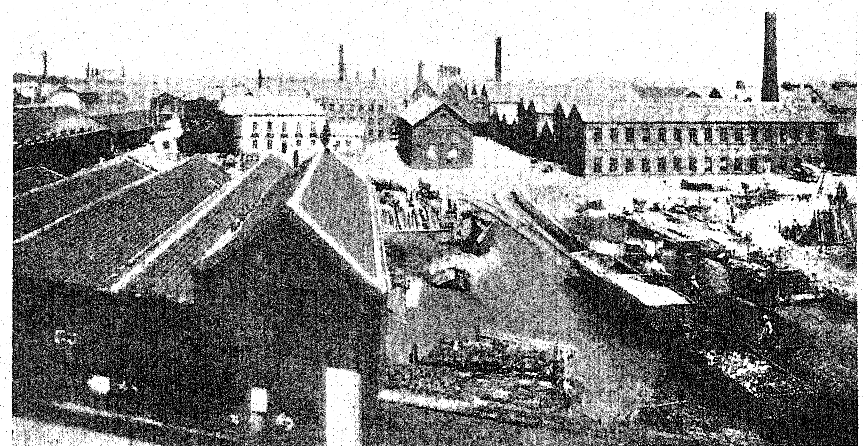


FIG. 133.—Boch Frères' works, La Louvière, Belgium.

in the north of France, principally engaged in making pavement-tiles; also dépôts at Bruxelles and Paris. They have showrooms at Lille, Hamburg, and Leipzig; and claim a long line of medals and honours at numerous international exhibitions from 1847 onward, including a Grand Prix at Paris in 1889.

In Holland.—As we have already seen, one pottery in Delft escaped absolute extinction, and the industry was revived in the latter part of the nineteenth century by Joost Thooft and Abel Labouchere. On 25th May 1890 the former died and left the works entirely in the hands of Labouchere, who, with skilful artist-collaborateurs, including Le Comte, has again earned high distinction in ceramics for the little Dutch town of Delft. But we

understand that the old stanniferous enamelling process is not now pursued to any great extent, the work being now done by English processes and largely with English materials. One interesting introduction has been the manufacture of hard-fired polychrome stoneware (under the direction of the technical manager, H. W. Mauser), of which decorative panels are composed by means of sections cut and formed separately to suit the outlines of the design, after the manner of mediæval Indian tile-mosaic, but so as to resemble in some degree the effect of stained glass. (See *Brick*, July 1903.)

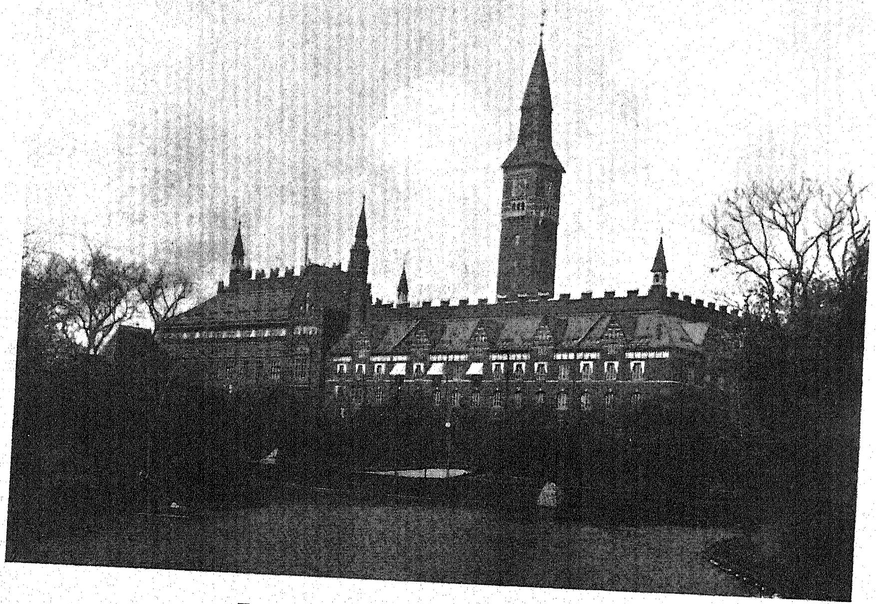


FIG. 134.—New Town Hall, Copenhagen.

Of other firms engaged in the manufacture of glazed tiles in Holland, two who merit special mention here are La Societe Ceramic, of Wijck, near Maestricht, and The Fayence and Tegel Fabrik, of Helling, near Utrecht.

Denmark furnishes few old associations of which we are cognisant in connection with ornamental tiles and architectural faience. The ancient Cathedral of Roskilde (the former capital of Denmark, about twenty miles from Copenhagen), consecrated 1084, holding the dust of many Danish kings and queens, including, it is said, King Canute's father and grandfather, appears to have no mediæval tiles. Neither have the castles of Kronborg, Rosenborg, or Fredericksborg any historically interesting faience in their construction as far as we can ascertain; although of Fredericksborg it is said

"many of the rooms are elaborately beautiful, and contain a wealth of works of art and costly furniture, the castle having now been transformed into a national museum"; and of Rosenborg, "a chateau of smaller dimensions, but possessed of great beauty; within whose red walls is harboured a unique collection of *objets d'art*, jewellery, furniture, etc., which has come down from the Danish kings and queens of the last four centuries." (*Danish Life in Town and Country*, pp. 64, 65, Newnes.)

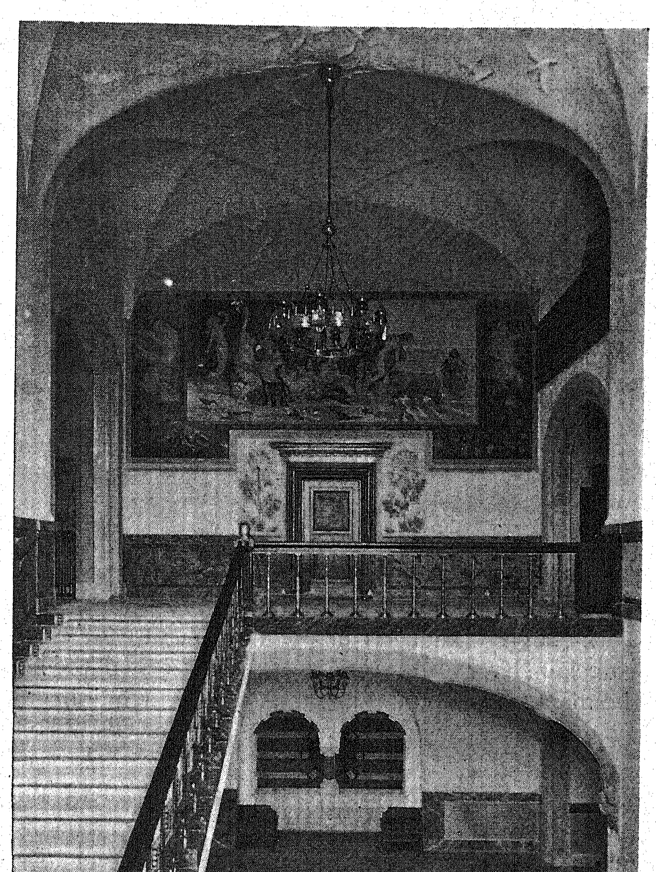


FIG. 135.—Interior, Town Hall, Copenhagen.

Even at the present day only one tile factory of the artistic class is, we understand, in operation in Denmark, namely, that of Hermann A. Köehler in Nastred (South Zealand). Here, however, some most beautiful architectural decorations in glazed tiles have been manufactured for modern erections; for instance, in the new Town Hall, Copenhagen.

About twenty-five years ago the Fayance Fabriken, at Aluminia, Copenhagen, executed some work in this style, but subsequently discontinued.

The Royal Porcelain Works, Copenhagen, was originally started in 1775 by a private firm. Shortly afterwards it was taken over by the State, but in 1867 it again passed into private hands; and in 1882 it was purchased by the Aluminia Co., who have, since that date, carried on the two establishments side by side. And it is to the kindness of the managing director, Dalgas, I am indebted for most of the few notes on Danish work.

There are potteries on the island of Bornholm, where china clay is found: but, so far, tile manufacture does not seem to have been attempted there.

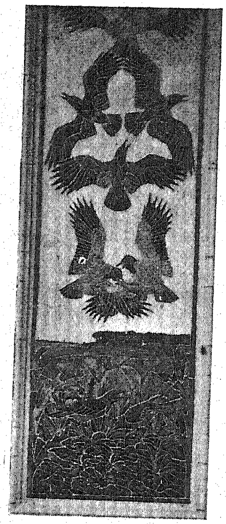


FIG. 136.—Detail of interior, Town Hall, Copenhagen.

In Germany the most eminent makers of decorative tiles and faience probably are the versatile firm Villeroy & Boch, of Mettlach, Merzig, Wallerfangen, Dresden, and Schramberg. Their first works at Septfontaines (Luxembourg) was founded in 1767; and one by one, in the course of a century, have the other factories been built or acquired, until now they are undoubtedly among the leading ceramists of the world.

The Mettlach, Dresden, and Merzig works appear to be those devoted to the production of ornamental tiles, mosaics, fireplaces, and architectural faience and stonewares. Their several works being within easy reach of the famous clayfields of Westerwald, Rhine provinces, and the Rhenish Palatinate, they have many facilities and advantages that greatly contribute to their variety of product.

Dr. Forrer, in his *Geschichte der europäischen Fliesen-Keramik*, pays great attention to the manufactures of Villeroy & Boch. From Forrer we see that their wares comprise not only the whole range of products ordinarily met with, but also replicas of Renaissance, Persian, and Delft tiles in great profusion.

Utzschneider & Cie., of Sarreguemines, a very old-established and extensive works, largely engaged in the manufacture of earthenware, chinaware, and porcelain, have also in recent times interested themselves to some extent in the manufacture of architectural ceramic requirements. Some very excellent examples of their product are given in Forrer's work, plates cv., c., iic., xciii.

Wessels' Wandplatten Fabrik, of Bonn, also is largely occupied in the manufacture of glazed decorative tiles; and of this firm also Dr. Forrer illustrates some excellent products.

Other German makers who should be named are:—

Jacobi, Adler, & Co., of Grünstadt (Rheinpfalz).
Etchings & Löhne, Lufflerhain (Elsass).
Professor Lenga, Karlsruhe.
Gebr. Meinhold, Schweinsturg (Saxe).
Norddeutsche Steingutfabrik, Grohn (Hanover).

And the Austrian manufacturers:—

Josef Stenach, Turn Teplitz (Bohemia).
Aug. Rath, Krümmnussbaum.
Raschka & Co., Nesselsdorf (Mähren).

In Spain flooring quarries have been made in considerable quantity in Catalonia for a long period, and it is quite possible that the ceramic manufactures of Spain have been more or less continuously exercised from the time of the Romans. In a report issued about fourteen years ago, the United States Consul of Barcelona remarked upon the importance of the ceramic industry in Catalonia, on account of the large exportation to Cuba and the Philippines. How the changed circumstances of these dependencies have affected the industry we have not ascertained. Still, a few excerpts from his comments may be interesting. He remarks:—"Besides the common type of bricks, others are occasionally made and baked in the same oven, especially those called Roman tiles. These, which were formerly used throughout the country, are now everywhere discarded, on account of the cheapness and lighter weight of the mosaic tiles which have taken their place. A short time ago the manufacture of floor-bricks constituted a very important industry in Catalonia; and although now, on account of greater exactions of style and luxury, it has somewhat lost ground, it still holds a high place among the Catalan industries. The bricks, which are 5½ inches square, are of two kinds, white and red. . . . . The floor-bricks which have acquired the most fame abroad are those manufactured at La Brisba, a small town near the city of Gerona, where the clay is of a particularly excellent quality. The manufacture of machine-made tiles is considerably developed in the province of Barcelona, where two important factories turn out a large amount of work. . . . . Formerly the clay used came exclusively from the mines of the towns of San Saturnino de Noya and Gelida, about thirty miles from Barcelona. . . . . An important industry, not so much on account of the number of usages to which they are dedicated, as for the great number manufactured, is the making of glazed bricks for kitchens, the shape and condition of which in Spanish cities is well known to consist in a number of small iron furnaces or grates, at a certain height from the floor, set in masonry, to cover which the above-mentioned bricks are used. These, the manufacture of which is almost exclusively confined to Catalonia, are used throughout Spain, the Philippine Islands, and the Spanish colonies in America. In mosaics there are two distinct kinds, both used as flooring—one of which, the older, is obtained by the juxtaposition of numerous pieces of geometrical shape, and each of a different colour. . . . . The difficulties already mentioned, and the restrictions which the geometrical shapes of the pieces imposed upon the general design, have given rise to the manufacture, in modern times, of incrustated mosaics. In this, as in its sister industry, natural clays are used. . . . . The colours are produced by various metallic oxides mixed in proper proportions. . . . . In the manufacture of incrustated mosaics all kinds of designs are obtained with the same clays used in simple mosaics, the difference consisting in the moulding. . . . . The shape is always square, with sides of 2½ inches or

more. The designs are obtained by placing slips of tin within the stamp matrices, and each one of the intermediate spaces formed being filled with the different clays previously coloured. The designs thus obtained, the slips of tin are removed, and the whole rendered compact by pressure." (*Jour. Soc. Arts*, 7th June 1889, p. 634.)

Among the principal makers of glazed tiles in Spain the following may be mentioned by name:—

Escofet Jereja y Cia., of Barcelona.
Fortuny y Angarill, "
Pujol y Bansio, "
Romen Escofet, "
José Gartner, 86 Calle Granada, Malaga.
Pastor y Cia., Reding, Malaga.
Francisco Viana Cardenas, Malaga.
Catala & Co., Manises.
Gornez Devis, "
Juan Mouleon, Valencia.
Pedro Llorca, Orfila, Sevilla.
Jose Regas, Rivamontan Al-Mar, Santander.

In Italy the manufacture of majolica is reviving; forty-three firms are mentioned in *Rousset's Directory*, but it is not stated which of these devote themselves entirely to the making of tiles and decorative wares. The Secretary of the Italian Chamber of Commerce of London has, however, kindly supplied the following list of makers:—

Societa Ceramica Richard-Ginori, Milano,
Societa Ceramica Ferrari, Cremona.
Societa Canavese, F. Stella & Co., Torino.
Stablimento Ceramico, G. Appiani, Treviso.
Candiani Dott Napoleon, Venezia.
Cacciapuotti Ettore, Napoli.
Patriarca, M., Catania.

And among other firms mentioned elsewhere are:—

Fabbrica di Ligna (Bonda).
Sperando Bros., Vietrie.
Salvini, Via Vitt. Emanuele, Firenze.
Guglielmo Cocchi e Figli, "
Cantagalli, "

In Russia the position of the decorative tile industry appears to be relatively insignificant as a home industry at present. Rousset gives no

Russian names in the list of faience-tile manufacturers, and only mentions fifteen firms in the list of unglazed-tile makers.

The British Consul-General at St. Petersburg courteously writes that glazed decorative tiles are not manufactured in that consular district, but are imported into the country mostly from Germany, Great Britain, and Finland.

And H. Montgomery Grove, British Consul at Moscow, states that decorative glazed tiles are in considerable use in Russia for grates, stoves, etc., and are also manufactured in the country, to the best of his belief.

In Turkey, Rousset mentions only two names of tilemakers in Constantinople, and these do not appear in the glazed-tile class. Mr. Hamson, of the British Consulate, kindly informs the writer that, as far as his knowledge goes, glazed tiles are not now being made in Constantinople, but that they may be made in Kutahia, an ancient town near Brussa, celebrated for its beautiful glazed tiles.

Persian.—In Persia, unless considerable improvement has taken place recently, what has been done in the way of art-ceramics has not earned much praise. In *Persian Arts*, Sir R. Murdoch Smith expresses himself unreservedly thus:—"The art of pottery gradually degenerated in Persia after the time of Shah Abbas, since whose reign nothing of much value has been produced. The earthenware of the present day, as regards both workmanship and material, is of the commonest description." (*Persian Arts*, p. 11, Chapman & Hall.)

And Mr. W. Simpson, in 1892, said:—"The part of Persia through which I passed had been so utterly devastated by the Turcoman raids, scarce a vestige of anything ancient remained. At Meshed only I saw a gateway built with sun-dried bricks and covered with ornamental glazed tiles, but it was a very poor specimen of art; yet it told me what might be done in this style if the work could be put into the hands of real artists." (*Jour. Soc. Arts*, 3rd June 1892, p. 207.)

The British Consul-General at Ispahan very courteously writes saying that "glazed blue tiles are made and used now in Ispahan." And in *Rousset's Directory* the names of two art potters at Teheran appear. It is highly probable that at Koom and Kashan also ceramic art still survives.

Some years ago Sir C. Purdon Clarke, C.I.E., the present Director of the Victoria and Albert Museum, South Kensington, while superintending the building of the new British Embassy at Teheran, had a glazed faience fountain made there. This was brought over to England and erected in the Victoria and Albert Museum; and he takes pride in the fact that, although water has been running over it for twenty years, it is good yet. In the photograph of the fountain which we have been kindly allowed to reprint, it

may be noticed that it is in a glassed recess, to facilitate the work of students; the ivy or creeper on the right is out of focus, unfortunately.

FIG. 137.—Sir C. Purdon Clarke's Fountain, Victoria and Albert Museum.

By the courtesy of C. Stanley Clarke, Esq., of the Indian Section, V. and A. M., the writer has had the opportunity of copying a monograph, by a Persian, upon Modern Kashi Earthenware Tiles and Vases. Whatever may be its intrinsic practical value, it is certainly interesting, and as it is apparently out of print, and entirely forgotten even at the Museum of Science and Art, Edinburgh, where it was originally published, the writer ventures to hope its reprinting in full will be excused by the utilitarian, and welcomed by the archæologist. This is done with the consent of both D. J. Vallance, Esq., of Edinburgh, and C. Stanley Clarke, Esq., London.

ON THE MANUFACTURE OF

MODERN KĀSHI EARTHENWARE TILES AND VASES

IN IMITATION OF THE ANCIENT.

WRITTEN AT THE REQUEST OF MAJOR-GENERAL SIR R. MURDOCH SMITH, K.C M.G.,

BY USTAD ALI MOHAMED OF TEHERAN,

AND TRANSLATED FROM THE PERSIAN MS. BY JOHN FARQUES, ASSISTANT SUPERINTENDENT, ENGLISH TELEGRAPH STAFF IN PERSIA, MEMBER OF THE ASIATIC SOCIETY OF PARIS, ETC., ETC.

MUSEUM OF SCIENCE AND ART, EDINBURGH, 1888.

ON THE MANUFACTURE OF

KĀSHI EARTHENWARE.

The master, Ustād Ali Mohamed, the inventor of that process, son of Ustād Mahdi, architect, native of Ispahan, and at this date, A.H. 1305, a celebrity in Islam, has allowed the humble scribe, Mirza Ali Mohamed, to write a pamphlet displaying the secret and describing the process of the art; and as the best deeds are those which award most profit to the doer, the writer has wished to explain how to procure the ingredients and requisites of that beautiful art, in order to acquire a good name amongst those who pursue it.

By order of the master, the writer has divided the subject in five chapters.

CHAPTER I.

How to procure the ingredients with which the coating (La'ab) is made.

You gather glasswort (shoora-i-brābani), and burn it till it turns to ashes. Its alkali (kelā) collects among the ashes. Take this alkali.

In the quarries is found a white stone which the Persians call seng-i-chekhmāq (a kind of flint). At Ispahan, in the river Zeyeudeh-rood, it is found in great quantity, the water carrying it down from the hills. In Nayin and Ardastan, two villages of Ispahan district, a very good quality of that stone and of shoora is found—in fact, this is the best of all places. The stone is to be found also at Koom, and in the neighbourhood of Tehran, in a hill called Bibi-shahrbanoo.

Anyhow, procure the stone whencesoever you can, pound it fine with an iron hammer, then mix one part of it with an equal part of kelā (alkali),

place it in the kiln, which heat. Keep on making fire, and with an iron poker keep stirring the compound, till the stone and kelā melt and flow into a basin which you have made under the kiln. On cooling, it will be found to resemble hard glass. It is called alkali-paint (rang-i-kolai). We must send you a sample.

Now, with an iron hammer pound fine this alkali-paint glass (shisha-i-rang-i-kolai), and pass it through a fine sieve. Then procure two quarry stones, called "shahdanej," so hard as to resist calcination. Set up one of these stones, and with an iron bore make a round hole in the middle of the other, fit a wooden handle to its edge, place it upon the first, and pour gradually the sifted glass into the hole, twirling all the time the top stone, until the glass-paint has become as fine as collyrium (surma). We will send a sample of this also as a criterion of the degree of fineness. Set aside this fine paint.

Melt in the kiln one maund of lead (surb) and one quarter maund of tin (gal). But I must explain how to do this. Take an earthen vessel, on its sides make two holes opposite to each other, place it in the kiln, throw in the lead and tin, stop up the mouth of the vessel, and heat the kiln so that the flame enters from the back hole of the vessel and comes out from the front hole, in such a way that the fire clasps the lead and tin from above and below. Thus you keep on heating till the lead and tin melt. After melting, you decrease the fire gradually, till the melted lead and tin give forth a froth (kurk); then you remove the lid of the vessel, and remove to one side the froth; again decrease the fire, froth is again formed, which you remove as before, and so on, gradually reducing the fire and taking off the froth until the whole of the lead and tin has turned into froth.

You take it and bray it fine on a stone. Then take four parts of the previously mentioned refined paint, and one part of this lead and tin turned into froth and brayed, and mix them for a coating or varnish (la'ab). Keep this kind.

CHAPTER II.

How to make another coating (La'ab) which is especially used for work of a superior quality.

You must take some of the above-mentioned alkali (kelā), put it in a kettle (fatilcheh), place it on the fire and boil it (adding the necessary water). After boiling, pour it into an earthen bowl and leave it all night. Next morning you will find at the top the essence of the alkali or kelā, crystallised in forms of ramifications like sugar-candy (nabat) or winter ice—the refuse sinking to the bottom.

Take this essence (janher), which the master of our art calls "essence of alkali." Take one part of this, mix it with one part and a half of flintstone (chekhmāq), very, very finely pounded—finer even than the former fine flint;

pour as much as you like of this mixture in ten to fifteen earthenware vessels, and place them all round the kiln, thus filling up all the space round the kiln. Then you heat the kiln. At first it will smoke a little; after two hours the smoke will cease and the colour of the fire will turn red; heat again, and after another two hours the fire will become white. Then look: you will see the contents of the vessels melted and shrunk. Let the kiln cool, then remove the vessels, break them, and preserve the contents, which is a kind of paint (la'ab), looking like hard glass. Pound it fine with an iron hammer, and then pass it through a sieve. Take four parts of this substance and one part of the froth of lead and tin prepared as before described, mix them, and again place the mixture in earthenware vessels, and, as before, set them all round the kiln. Heat the kiln till at first the fire smokes, then turns red, then white, at which the contents of the vessels melt. You again let the kiln cool, remove the vessels, break them, and preserve the contents. This you pound with an iron hammer, pass through a sieve, and bray—the finer the better. This paint or drug (la'ab or deva) is especially required for work of superior quality.

CHAPTER III.

How to make the paste of the bricks or vessels; with what difficulty the workman procures the ingredients, and works them up, etc.

Pound with an iron hammer some of the before-mentioned flintstone (chekhmāq) and pass it through a sieve, then bruise it well in the millstone, which I have before described, till it becomes fine—the finer the better.

We have a kind of clay of a white colour, the mine of which is at the village of Vartoon in the Ispahan district. The master of our art calls it fireclay (gil-i-bootah, literally crucible clay). It is to be found at Tehran also, but not of such good quality. Put some of this clay in water, so as to form a sort of whey-water (doogh-ab), and pass it through a rag.

Now take eight parts of powdered flintstone (chekhmāq), one part of dry fireclay (gil-i-bootah), and one part of that stone and alkali which you had first burnt with the refuse. (This refers to the first la'ab, in first chapter, *i.e.*, the kelā and chekhmāq stone, well bruised.) Mix the three together, and with the doogh-ab make a paste—owing to the presence of the gil-i-bootah they will stick together. Take a handful of this paste, roll it out on a flat hard surface, and with a mould, made of plaster, shape your bricks until all the paste is used up: let the bricks dry. If you wish to make figures or flowers in relief on the bricks, you must, while they are still a little damp, smooth the surface with a special tool (abzar-i-makhsooseh), and with a plasterer's engraving tool (qualam-i-gaehbur) make your designs. When dry, and before applying the colours (neqqashi), the bricks require a coating (la',āb), which is made as

follows:—Bray some very white chekhmāq stone in the manner before mentioned, take one part of it and one-eighth of gil-i-bootah, mix them together with water in an earthenware vessel till they form a solution (doogh-ab), wash with a damp rag the surfaces of any bricks which have dried up, and then spread the above solution over the bricks to the thickness of a tin-plate; keep the bricks inclined to let the excess drain off, and then set them to dry.

CHAPTER IV.

Different colours applied to and various designs made upon bricks and vessels. How to procure and mix the ingredients of the different colours, etc.

First, procure a stone which men of the craft call "siah-qalam-i-ma'dani," and also another stone called "maghn." To as much as you like of the former you add one-tenth of the quantity of the latter; add water and bruise on a soft flat stone until the mixture becomes like syrup of grapes. With this you paint (using a hair-pencil) on the bricks prepared as above described any figure or design your wish or taste may suggest.

Now let us go back to the various colours which you require for your flower, figure, or whatever you have designed. Now, my friend, listen attentively, by order of the master of this craft I will give you a receipt with which you can do anything you like.

Put half a miscal of gold in aqua-fortis (tizab), dissolve a quarter of a miscal of tin (gal) in about a bowl (kasseh) of aqua-fortis, then pour the two solutions into an earthenware vessel containing 5 maunds of water; the water will turn red (qermez), verging to black; mix with it 32 miscals of crystal glass, well pounded to the fineness of collyrium (surma); it will then throw up a red froth, which will subside; pour away the water which is at the top, put 4 miscals of dross of gold (murdeh sang-i-tela) with the deposit—(to melt gold one uses lead and water; when the melted gold is removed, the refuse, lead, water, and dross of gold, is the murdeh sang-i-tela meant here)—add also 2 miscals of "tanagār" (a dissolvent similar to borax), bray the whole well, and with a hair-pencil you may paint with this "deva" any part of your sketch which you wish to come out red.

Now for what you wish to colour in cerulean (lajverdi). In the environs of Kashan is a hill with a mine of this lapis-lazuli (lajverd-khak)—(not the real lapis-lazuli, but a cobalt ore)—this lapis breaks out of the hill like blossoms. Every few years the inhabitants of Kashan collect some of this blossomed earth and make it into bud-shaped balls. Men of the craft buy these lapis-lazuli buds, pound them, and add half the quantity of Yezd borax (booreh-i-yezd), such as goldsmiths use, and half the quantity of essence of "tanagār," which blacksmiths use, and which comes from Khorasan. The three mixed together you put in an earthenware vessel, place it in the kiln, heating till, as

in previous cases, the compound melts. Let the kiln cool, remove the vessel, and break it; break open also the contents, which will be found to enclose a white substance like silver. Keep this and throw away the rest. Take now one part of this silver-like substance, one part of these raw lapis-lazuli balls, and one part of chekhmāq stone, finely pounded, mix and bray all these very fine. This is the cerulean colour, as men of the craft like it. If the colour is too deep, add some finely bruised chekhmāq stone—the more of which you add the paler will be the colour.

If you want a turquoise colour (rang-i-firoza), know that when copper is heated and hammered it gives off a dross (risesh). Mix one part of this dross, well pounded, with half a part of pounded chekhmāq stone, and you obtain turquoise colour, any place you paint with it coming out of the fire turquoise colour.

If you want violet colour, take one part of the red colour above described, and mix it with one-third part of cerulean, bray the mixture, and you have violet colour.

If you pound the "maghn" stone raw and paint with it, you will have iris-violet (benefeh-i-zanbaki).

For yellow colour, men of the craft procure from Khorasan a kind of clay called ukhrā (ochre); they extract the essence of the refined part of it, which, when pounded, becomes yellow paint. Another kind of yellow colour is procurable at the alchemists (meshshaq). Green colour is also procured, if necessary, from the alchemists.

CHAPTER V.

Varnish (La',āb) after applying the colours.

Now we must write a chapter about the varnish (la',āb) which is put on the bricks after the colours have been applied. Take a little of those two kinds of varnish which we have made, cooked, and put aside in chapters I. and II., place it in an earthenware vessel, take some gum-arabic (kativa), infuse it, clear it, and add it to the varnish, mix, adding water until the compound becomes as fluid as doogh water. Then spread this varnish over the bricks, keeping them inclined so that the excess may run off; then lay the bricks horizontal to dry; when dry, set them round the kiln, as you would set looking-glasses, and apply the fire.

The master of the craft says, first for two hours make a light fire till the surface of the bricks gets black, then increase it a little for two hours, when the black changes to red, then for three hours make a moderate fire, that is not too strong so as to produce smoke, and not too light, lest the colours dry up again; this fire must be kept on till the varnish becomes clear. At this

point stop the opening of the kiln, and let it cool down for two or three days, when the bricks may be removed.

This first process is finished. It is the work of our master, and is known as drawing under varnish (nagsh-zir-la',āb). The fuel you burn in the kiln must be white and dry wood, in order to avoid too much smoke.

END OF PART I.

PART II.

SEVEN-COLOURS PROCESS.

From the master of the craft we have learned another process which is known as the "seven-colours process" (haft-rang-sazi). It is of two kinds: one consists in making each brick of one uniform colour, the other in making one brick of seven colours.

Should you wish to make vases, the paste must be of the chekhmāq stone, before mentioned; and if you wish to make bricks of seven colours, or of one uniform colour, you may make them with potters' clay (khak-i-russ), provided that in order to decrease the strength of the potters' clay you mix with it a little sand, which Persians call "masseh," or even a little ashes.

Aye, my friend, to make vases you must pound the stone as before, but if for easiness' sake you make bricks of potters' clay, mixed with ashes, you may do so, there is no harm. If you want to make vases you take chekhmāq stone, well pounded, fireclay (gil-i-bootah), and the stone and alkali (kelā) previously mentioned, mix them together as we have before taught you so as to form a paste, and on the potter's wheel turn it into the shape of a vase.

To make a brick, the master takes a wooden mould, fills it with potters' clay, well handled, and mixed with ashes or sand, then with a wire he cuts off the excess paste; he then turns the mould over on the ground and so leaves it for twenty-four hours. Next day he removes the mould, beats and presses the brick on a flat stone to smooth its surface, then places it upright against the wall, so as to dry without warping. When dry he rubs the surface with a damp rag and begins colouring.

CHAPTER I.

How to make colours special to the "seven-colours process" for bricks or vases.

Bray as before 3 parts of lead and 1 of tin, add to them 6 parts of that glass-like paint before mentioned, put all in a vessel of water with a little clear gum-arabic. With this, paint the brick uniformly, place it in the kiln, using only half the previous degree of heat for this the "seven-colour process."

On removing the brick from the kiln it will be found to be white—the effect of the above drug.

If you want a turquoise colour, add to that colour which has come white out of the kiln one-sixteenth of copper dross (tufalisnes—the pieces which chip off when copper is hammered)—place it in the kiln, and heat. It will come out of a turquoise colour.

If you want a yellow colour, take 16 parts of lead and 1 of tin, melt them together, take the froth (kurk) and heat it; when it begins to melt, add a quarter of its quantity of well-brayed stone and mix thoroughly. Bricks or vases painted with this preparation and heated will come out of the kiln a yellow colour—like a servant who has acted perfidiously, and who, as is well known, turns yellow.

With an iron ladle (sikh), skimmer-like, you must take out that yellow colour when melting, bray it, mix it with a solution of gum-arabic (la',āb-i-kativa), and apply it to bricks or vases. This requires only half the heat of other colours.

If you want black colour (meshki), mix and bray together 3 parts of crystal glass, 4 parts of the glass-like paint, and 1 part of "maghn" stone; add some liquid gum-arabic, and 8 miscals of essence of alkali well bruised. This requires the same degree of heat as the white colour, and comes black out of the kiln.

If you want a cerulean colour, this is the process. Take 5 seers or 1 part of lapis-lazuli raw, 15 seers or 3 parts of crystal glass, 4 parts of the glass-like paint, 1 miscal of essence of lapis-lazuli, and 8 miscals of essence of alkali; bray the whole, adding clear liquid gum-arabic and water. Apply this to bricks or vases, place them in the kiln with full heat. They will come out a cerulean colour.

If you want a green colour, bray and mix 1 part of copper dross, 3 parts of vermilion (surenj), 6 parts of crystal glass, 6 parts of chekhmāq stone, and 6 parts of the glass-like paint; add water. Apply to bricks or vases, heat them in the kiln, and they will come out green.

If you wish to have a red colour (qermez), take half a miscal of gold in a vessel containing aqua-fortis (tizab), dissolve 6 nukhuds of tin in aqua-fortis in a separate vessel, fill an earthenware vessel with water, add the gold solution and stir briskly; now add the tin solution. It will turn the water red, verging to black; add 30 seers, Tabriz weight, of pounded crystal glass. The water will give forth a froth and make a sediment; throw away the water, add to the sediments about 30 seers of the glass-like paint, mix all well. Bricks or vases painted with this compound (deva) will, when heated in the kiln, come out red. If you mix 1 part of this red paint with 4 parts of cerulean colour you get a violet paint (benefsh).

Again, put iron filings (suvaleh-i-ahen) in aqua-fortis, and let them stand

for some days; they will have a chemical action on each other (eat each other) and become the iron saffron (zaferan-ul-hadid—burnt-green vitriol); mix with water, and use as paint; it will give an orange or jujube colour (naranji or annabi).

CHAPTER II.

Seven colours on one brick.

But if you want one brick to come out with seven colours (this does not mean superposed colours, as in the "Reflet," but seven designs each with a different colour), you must first prepare the seven colours and test them, counterbalancing the moisture and dryness of the ingredients so as to obtain equilibrium. Then you begin, following the direction of the master I have written it all down.

Know, first, that a brick which comes out of the kiln white is fit to receive the seven colours. Now let us make anew the colours, so as to get colours special to the seven-coloured bricks. First, take 2 miscals of essence of lapis-lazuli, 4 miscals of budlike balls of raw lapis-lazuli, 30 miscals of pounded crystal glass, 30 miscals of pounded chekhmāq stone, 30 miscals of tanagār, 30 miscals of essence of alkali: bray all together, put in an earthenware vessel, and place it in the kiln; heat up, take out, break the vessel, bray the contents, and add water. This is the cerulean of the seven-coloured process.

When you want a green colour, take 4 miscals of copper, 4 miscals of lapis-luzuli, 30 miscals of crystal glass, 30 miscals of flintstone, 30 miscals of essence of alkali, 30 miscals of saltpetre (shoora-i-qalam); mix all in a vessel, put in the kiln, take out, break the earthenware vessel, bray the contents, apply it to a white brick, and it will come out green.

For turquoise, you must take 4 miscals of copper, 4 of lapis-lazuli, 30 of crystal glass, 30 of flintstone, 30 of essence of alkali, and 30 of saltpetre; put in a vessel and bake. It will come out turquoise paint.

For black, take 4 miscals of "maghn," 30 of crystal glass, 50 of chekhmāq stone, 30 of essence of alkali, 30 of saltpetre; mix in a vessel, bake, bray, and you will have black paint.

For red take half a miscal of gold in aqua-fortis, also 6 nukhuds of tin (gal) in other aqua-fortis, fill a bowl with water, and add the gold solution, stirring briskly; next add the tin solution, stirring it with your hand, the froth will set, pour away the water; add half a Tabriz maund or 320 miscals of crystal glass, and 110 miscals of "tanagār," and bake in an earthenware vessel. The compound will be red paint.

For violet (benefsh), mix 4 parts of this red colour and 1 part of cerulean (lajverd), and you will get violet paint.

The method of testing is this: paint those seven colours (separately) on a piece of brick, and place it in a portable kiln, which you heat. Taking the

brick out, examine it; any colour which is dry, unclear, dull, must be increased in moisture according to the degree which each requires.

After thus regulating the strength of the colours (raising what is too low, lowering what is too high), apply all the seven colours separately, by making a design with each on a brick or vase, and cook it in the kiln in the way before described.

These seven-colour bricks want only half the degree of heat required for the previous process. Let the kiln cool down for twenty-four hours, then draw out.

This is called the seven-colour process (haft-rang-sazi) and supercoloration or kar-rooi-rang. The pamphlet is finished. To him who ordered it, and to the master of the craft. Hail!

TEHRAN, 1888.

N.B.—1 maund Tabriz weight = 40 seers.
1 seer ,, ,, = 16 miscals.
1 miscal ,, ,, = 24 nukhuds.

C. Stanley Clarke, Esq., appends a note that 1 seer = about 1 kilo.

It should also be noted that "lapis-lazuli" is apparently used to designate cobalt bloom; that "aqua-fortis" is frequently used where clearly "aqua-regia" is intended; and that the term moisture is used for fluidity in a vitreous state or for glassiness. Words such as "maghn," "ukhrā," "kelā" have a peculiarly familiar sound.

Indian.—In India, as far as the writer has been able to learn, the decorative tile industry is now in a state of decline rather than of progress; a flickering out of an ancestral art, the fashion and glory of which came and departed with Muhammadan and Moghul supremacy; "*other times, other manners.*"

The late Edmund W. Smith wrote, "The art has almost died out"; and Sir George Birdwood, K.C.I.E., states that in mediæval times there was a far larger output of tilework than at present.

What of it is left seems to be linked hereditarily with that of mediæval times; the types of design, and even the particular shades of colouring, wherever of indigenous origin in Sind and Panjab, partake of the old styles. In Panjab, in particular, Sir George Birdwood says yellow was largely used in painting the tiles, and occasionally red, but dark and light blues were, and are now, the predominating colours used in the Panjab. In Scinde a tawny yellow, almost brown, is still used, also green and a dull purple.

The Indian Section of the Victoria and Albert Museum, South Kensington, contains remarkable examples of glazed and enamelled terracotta and tile-work made for and at the instance of Sir C. Purdon Clarke, C.I.E., some years ago, at Tatta (Lower Sind) and at Mooltan and Lahore; also specimens of

the glaze frits as actually prepared by kashigars in India. By the kind permission and assistance of C. Stanley Clarke, Esq., of the Indian Section, V. and A. M., examples of Indian work (fig. 138 and fig. 139) are illustrated in this volume.

The Mûltan tomb (fig. 138) is of glazed tiles, decorated with conventional plant forms, floral and leaf ornament, and inscriptions in two shades of blue and white. It is a copy of a tiled tomb near the Mosque of Yusuf Shah Gadez at Mûltan. Made at Mûltan; nineteenth century.

The wall-panel and niche (fig. 139) is of glazed tiles, decorated with geo-

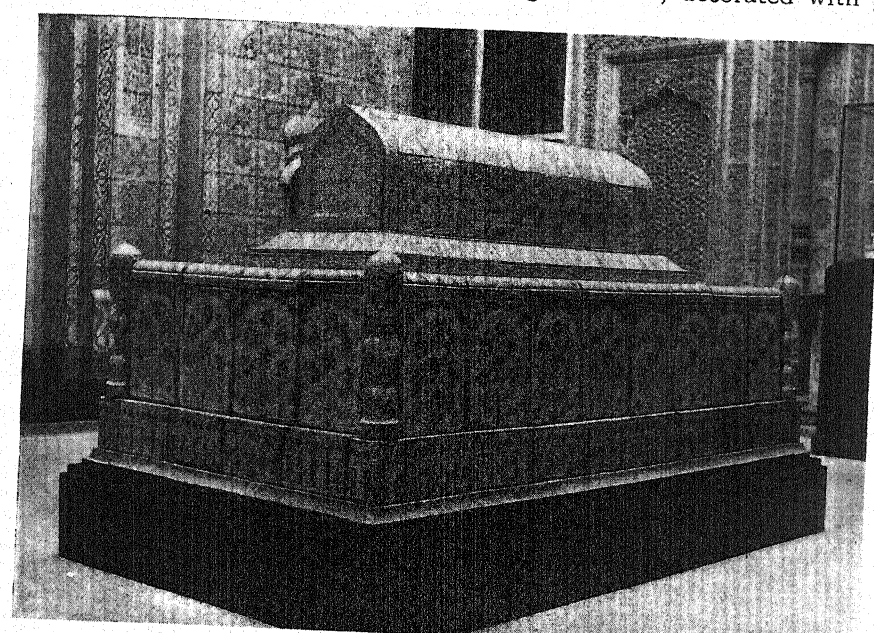


FIG. 138.—Tomb of glazed tiles. Made at Mûltan. Nineteenth century. Now in Indian Section, Victoria and Albert Museum. (*Illustrated by permission of C. Stanley Clarke, Esq., Indian Section.*)

metrical and conventional floral patterns and an inscription in two shades of blue on a white ground. It is a copy of part of the exterior of the tiled wall of the Mosque of Yusuf Shah Gadez at Mûltan, which is of eighteenth-century work. Made at Mûltan; nineteenth century.

By the kindness of Mr. C. W. Tawney, Librarian of the India Office, Whitehall, the writer has had an opportunity of perusing several special monographs relating to pottery-making in Bombay Presidency and in the Panjab. From these sources principally the following notes have been compiled:—

The common red-ware potters, of whom there are many—called kumbhārs, from kumb, a water-pot—are mostly of one or other of the castes of Hindoos.

The glazed-ware potters, who, according to Mr. Maconochie, are few, are called kashigars, and trace their descent from some prehistoric chinaman who was induced by one of the Amirs to settle in Sind.

Mr. Maconochie says:—"Glazed pottery is manufactured at Hāla and Nasarpur of Hyderabad, Sind, and in the Nanshāhro Tāluka of the same district, at the J.J. School of Art and the Perozeshaw Pottery Works in Bombay, and at Pattan and Ahmedabad in Gujarat"—the Hāla ware holding pre-eminence for beauty of design and richness of colour.

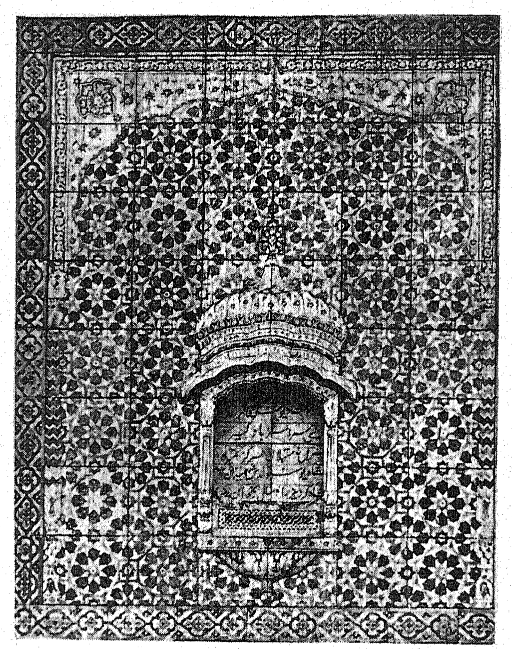


FIG. 139.—Muhammadan wall-panel and niche. In the Victoria and Albert Museum, Indian Section. (*By permission.*)

He tells us that "at Hāla the work is carried on separately by two families, that of Nur Mahomed, and that of Usif, son of Kabil. The earth is obtained from the local tank, and the colours come from the Panjāb. The favourite articles of manufacture are tiles, which are used largely as head-stones for graves and ornamenting mosques, as well as for floors and ceilings. The method of preparing the tiles is as follows:—The tile is cut into shape in the rough clay by means of a standard tile, and is then sun-dried. A coating of fine white clay is then spread over the tile, and on this the pattern is painted. Metallic pigments of manganese, cobalt, and copper are used. Over the painted pattern the glaze is placed in a pulverised state, and the whole is then fired. The glaze is of three kinds: colourless, green, and brown. In the process of firing the body of the tile becomes earthenware, the finer clay porcelain, the patterns take their proper colours of purplish black, azure, and green, and the glaze becomes transparent glass. The glaze is composed of the base of sand and litharge, 6 of the former to 20 of the latter. The green colour is obtained by the use of oxide of copper, brown by karmaji, or oxide of iron, mixed with a little cobalt (auria). The sand used for the glaze comes from Sehwān, and the flint for the porcelain clay from Mount Anjar."

Of Nanshāhro ware Mr. Maconochie writes:—"A class for instruction in pottery is held at Kandiáro in connection with the industrial schools of that tāluka founded by Khán Bahādur Kádirdád Khán some eight years ago. There are about twelve pupils, and they are chiefly occupied in manufacturing tiles of different sorts, plain or coloured, glazed or unglazed, according to requirements, these being the only articles for which there is any local demand. . . . . Several thousand tiles have been supplied to Government for the construction of the new Mukhtyārkarates of Nanshāro and Kandiáro, the Central Jail at Hyderabad; and in 1894, when the repairs of the Juma Masjid at Tatta, in the Karachi district, were undertaken, the services of the pottery class were . . . . utilized in replacing missing or damaged tiles. The ornamental tiles find a ready market amongst the wealthy inhabitants of the subdivision."

The work at Bombay School of Art, or somehow connected with it, under Mr. Terry, is referred to. This seems chiefly pottery, with a body composed of clays from Cutch, Malvan, and Bombay, and quartz from Bhor Ghāt, and glazes made by a kashigar from Mooltan. (*A Monograph on Pottery and Glass of Bombay Pres.*, Maconochie.)

With regard to the Panjab, from the monograph by C. J. Hallifax, C.S., it seems that the art-pottery industries were in 1890–1891 in a rather small way—only five workshops, employing fifteen workmen, in Mooltan; five makers in Peshāwar; twenty-three workshops, employing forty workmen, at Rawal Pindi; and a number, not stated, at Delhi.

Mr. Hallifax writes:—"A trade in art-pottery exists only in Mooltan and Peshawar. Attempts have been made to introduce 'kashigari' into Amritsar . . . . but they have failed. The introduction of a sort of porcelain manufacture into Delhi has, however, been more successful, and Delhi is now noted for its white pottery. Vessels are occasionally glazed and coloured elsewhere than at Mooltan and Peshawar, but there is no regular manufacture as in those towns. A few potters, such as Muhammad Shānf of Jullundur, are still able to make first-class painted and glazed tiles, but the manufacture of glazed tiles, which was once so extensive, has practically died out in the Punjab."

Specimen tiles, about $5\frac{3}{4}$ by $5\frac{3}{4}$, of the Delhi white porcelain are shown in the Indian Section, Victoria and Albert Museum. They appear to be made of perfectly white siliceous sand or powdered quartz and gum, with a very little alkaline cement, and are decorated with floral designs in blues.

In a monograph on the *Pottery and Glass Industries of the North-Western Provinces and Oudh*, by H. R. C. Dobbs, C.S., published at Allahabad, 1895, and kindly placed at my service by W. G. Wood, Esq., Under-Secretary to the Government of the United Provinces, it is stated that "the art of glazing is known in sixteen districts, though in many of them it is practised on a very small scale. Metallic glaze is applied in Benares, Lucknow, Meerut, Mirzapur,

Farukhabad, and Fyzabad. Vitreous glaze is applied in Agra, Allahabad, Aligarh, Budaun, Bareilly, Benares, Bulandshahr, Farukhabad, Fyzabad, Lucknow, Meerut, Moradabad, Mirzapur, Muzaffarnagar, Pilibhit, and Rámpur. The trade is in most districts in the hands of kasgars, but is carried on in Budaun by manihars, in Muzaffarnagar and Rámpur and Meerut by Multáni kumhars, and in Chunar by Katris. In Allahabad glazed pottery is made in the Central Jail, but no account has been received of the process of its manufacture.

"Metallic glaze is made in three colours—yellow, green, and red. (1) The yellow glaze is made as follows:—Lead and zinc, in the proportion of one to eight, are put in an earthen pot, which is set over a clay hearth and plastered round with mud. They are melted up for two days, and the white scum containing the oxide of the two metals combined, which is called phûl, is continually skimmed off with a large flat ladle called *kalchul* or *kareha*; one-eighth part of borax and one-eighth part of powdered red-stone are then added, and the compound is again melted up for about seven hours. At the end of this time the molten mass is poured slowly into a wooden trough full of water, and coagulates at the bottom of the trough into separate pieces, which are at once taken out and ground to powder in a common stone handmill. This powder is mixed with very thin wheat-flour paste, and is then ready for application to the vessel.

"(2) *Green metallic glaze* is produced by the addition of one-eighth part of copper dust to the ingredients of the yellow glaze. Green and yellow metallic glaze are made in all the above districts.

"(3) *Red metallic glaze* is made only in Fyzabad and Chunar (Mirzapur). In Fyzabad it results from the addition of a small quantity of red oxide of mercury to the yellow glaze; and in Chunar, as far as could be discovered, from an admixture of quicksilver with the same.

"Metallic glaze, unlike vitreous glaze, is applied to the ware after the latter has undergone a baking of about seven hours. It is either applied with a brush, or the whole article is dipped into the basin of glaze. It is allowed to stand for about three hours, and then put back into the kiln and baked for six hours. Metallic glaze is never used for delicate ornamentation, and is only applied to pipe-bowls, the spikes, knobs, and classic vases with which native houses . . . . are adorned, and the pierced screens through which secluded ladies are allowed their only glimpses of the world.

"Vitreous glaze, its ingredients and application: the main ingredient in vitreous glaze is the native glass or Kánch. This is usually obtained in the form of broken glass bangles from the bangle-sellers. . . . . The bangles are ground up into a powder in a handmill and mixed with wheat-flour or rice paste. The glaze thus obtained is of a greenish white, and is spread over whatever colour the article to be glazed has received before baking. The

only colouring matter which is ever mixed up with the glaze before its application to the vessel is powdered copper, which turns blue when baked. In the case of all other hues the colouring material is first applied, and the colourless glaze spread over that to fix and protect it. The colours usually obtained are as follows:—

"White from chalk and gum, except in Rámpur, Budaun, Bulandshahr, and Meerut, where powdered white-stone and paste are applied.

"Red is obtained in most districts by merely spreading the transparent glaze over the uncoloured red surface of the common ware. But in Bareilly borax and red-lead are applied, and in Rámpur a red earth called bamri.

"Dark green from powdered copper and borax.

"Light green in Lucknow from powdered iron refuse.

"Yellow from red-stone, zinc, and lead melted together and then powdered.

"Orange at Bareilly and Benares from *hirmanji* earth.

"Blue from indigo at Rámpur, from *senta*-stone at Meerut, oxide of manganese and borax at Budaun, calcined copper and chalk at Lucknow. All the coatings which a vessel receives from the glazer, including the colourless glaze itself, are technically known as *nishasta*. . . . .

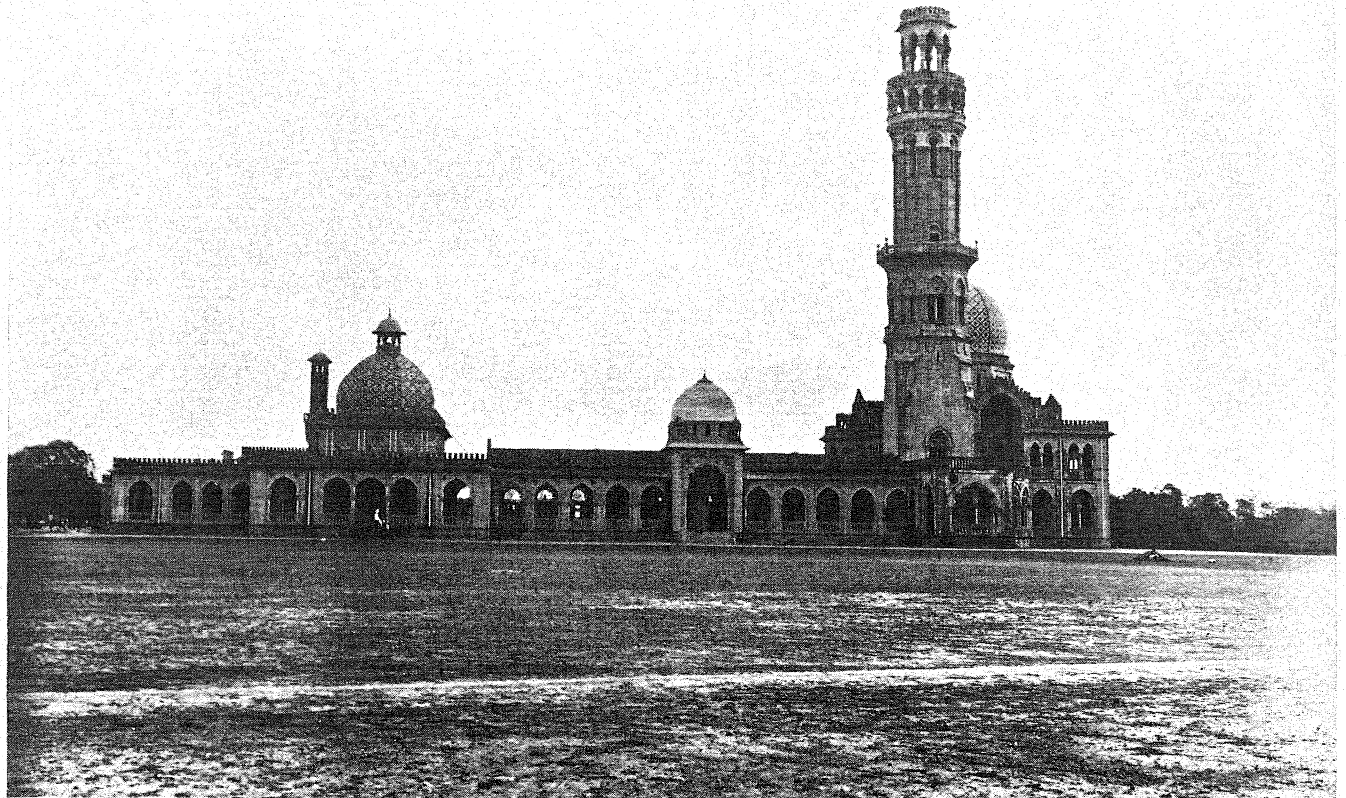
"After the vessel has been painted, either by the potter himself, or, in the case of fine pottery, by a professional painter, the glaze is allowed to dribble over it from a cup or saucer, or is splashed over it by the potter with his hands. The vessel is then dried for one day, and baked in the kiln specially used for glazed pottery. . . . . Vitreous glaze is applied to pipe-bowls, the saucers, cups, basins used by Musalmáns, and to all ornamental glazed wares." (*Pottery and Glass Industries of the North-Western Provinces and Oudh*, by H. R. C. Dobbs, C.S., p. 14.)

The practical ceramist will not have failed to observe one or two points, such as red from red-lead and blue from indigo, that appear to be erroneous; but, upon the whole, this little description of the ways of our fellow-craftsmen of India is not without interest.

Respecting glazed tiles, Mr. Dobbs writes in the same monograph, p. 18, "a glazed ornamental ware, decorated with heavy gilding and glazed tiles, were until recently manufactured at Sahâranpur"; and on p. 23, "Rámpur ornamental pottery closely resembles that of Khurja and of Bahadurgarh, and is said, like them, to have been originally introduced from Multán. It seems until lately to have been confined to the manufacture of tiles, slabs, etc., intended to be built into mosques and tombs."

With reference to Bengal, Taw Sein-ko, in his monograph on the *Pottery and Glassware of Burma, 1894–95*, makes the brief but significant remark: "It is a notable fact that the art of glazing is unknown in Bengal" (p. 11).

Respecting Burma, for several reasons given, he shows how it is that at



S. H. Dagg, Allahabad.] *Photo.*

University Buildings, Allahabad.

(*Illustrated by permission of W. G. Wood, Esq., of Naini Tal, Under Secretary to the Government of the United Provinces.*)

present ceramic art is in a low condition in Burma, and "does not now possess any pottery comparable with that of Sindh and Delhi."

As to the ability of natives of India nowadays, Sir C. Purdon Clarke, C.I.E., in a paper on "Modern Indian Art," read at the Society of Arts, 15th April 1890, while deploring the results of attempts to graft European designs upon Indian art-products, observed:—"All travellers in India know the wonders of the past, the temples at Abu, Akbar's dream in stone at Fathipur Sikri, and the Taj Mahal; but if they doubt that it is possible to emulate these works, it is only necessary to visit the modern cities of Khorja and Bulanshah to see that natives, working for themselves, can still design and do all the work they produced in the old time. Then the college buildings at Ajmere, Colonel Jacob's People's Palace at Jeypore, Mant and Chisholm's royal buildings at Baroda, and Chisholm's Government buildings at Madras, show how much can be done where Indian and European work together." (*Jour. Soc. Arts*, 18th April 1890, p. 519.)

The Muir Central College buildings of the University of Allahabad, which we are kindly permitted to illustrate (Plate XXVII.), are not perhaps representative of native art, but show the effect of British influence intertwined therewith. H. G. Boyce, Esq., M.I.C.E., F.C.H., Superintending Engineer, III. Circle, Provincial Works, has kindly explained that the two domes are covered with porcelain glazed tiles, six inches square, and that these tiles were obtained from the Minton works in England. The floors of the lecture-room are laid with Shurajpur and Agra red sandstone, and the floors of the library and Vizianagram Hall are of marble and mosaic-work.

United States of America.—Among the now rather numerous manufacturing companies in the States who produce ornamental tiles, we must, in common justice, refer, in the first place, to The Star Encaustic Tile Co., of Pittsburg, Pennsylvania; for the founder of this establishment, Mr. Samuel Keys, claims to be the father of the tile industry in the United States of America, so far as ornamental floor-tiles are concerned. Like many of the successful pottery manufacturers in the States, he hailed from the old country. Mr. Keys, we understand, was born at Derby, in England, in the year 1832, and went to America in 1862. Before leaving England he had acquired some knowledge of the manufacture of pottery, but had no practical acquaintance with tile manufacture; although one of his uncles—also named Samuel Keys—once upon a time was in the employment of Herbert Minton at Stoke-on-Trent.

In 1867, while managing a brickworks at Pittsburg, Mr. Samuel Keys conceived the idea of making tile, and began experiments with that object, denying himself rest and leisure, until in 1871 he demonstrated that he could produce all kinds of tints and clays for the purpose of manufacturing first-class tile. In the same year—thirty-three years ago—he exhibited tiles at an inter-

state fair and gained a diploma of merit, of which he has kindly sent a photograph. Shortly afterwards he formed a business partnership with Mr. David Hutchinson, a brick manufacturer of Pittsburg, for the purpose of manufacturing tile, and a small plant was erected and tiles manufactured. At the end of two years this business association was concluded; after which the present company was formed, with Mr. Alrich as the business head and Mr. Keys in control of the production. The plant has been in continuous operation since 1876. It is situated in Bluff Street, Pittsburg, and comprises several ovens and kilns, every one of them fired by natural gas.

The present plant and facilities of The Star Encaustic Tile Co. are capable of a product of about 400,000 square feet per annum, comprising all colours in vitreous goods and plain tile.

FIG. 140.—Inter-state Fair certificate, 1871.

Mr. Samuel Keys has now reached the mature age of seventy-two years, and reports himself still hale and hearty and good for twenty years' further active service. The firm state that they have not used a pound of coal for many years. They commenced to use natural gas about 1884, and have ever since employed natural gas in making and burning the tiles, namely, in all the kilns, for all the boilers, and for all lighting and heating purposes.

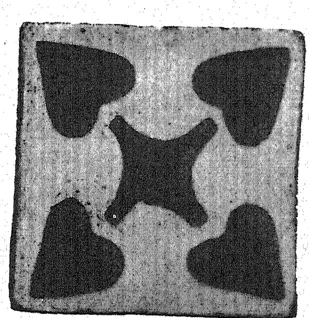


FIG. 141.—One of Mr. Keys' trial vitreous tiles made in 1867.

On 15th August 1903 a new company was incorporated at Trenton, N.J., under the title of The Colonial Tile Co., with a capital of £1,000,000. This company is intended to absorb The Star Encaustic Tile Co., of Pittsburg, and The Beaver Falls Art Tile Co., of Beaver Falls, Pa., and to erect large new works at Tiffin, Ohio. When this new plant is complete, it is to be one of the largest and most complete in the world—everything to be run by natural gas and most modern appliances.

Samuel Keys, Esq., Pittsburg, Pa.

The New York Vitrified Tileworks, of Brooklyn (N.Y.), manufacturers of vitreous floor-tiles, ceramic and cut mosaics, etc., was established in A.D. 1891 by Mr. A. H. Bonnell. This factory, it appears, is on the site of the old International Tile Co., which was established about 1882, and was one of the very few pioneer factories making glazed, printed, decorated, and enamel tiles, as well as encaustic and plain tiles. The raw materials are all from the states either east or south of New York State. The fuel used is coal of bituminous nature from Maryland. The New York Vitrified Tileworks Co. claim to be the first in America to make a speciality of vitreous floors and ceramic mosaics. Their yearly capacity in vitreous and ceramic flooring-tile is said to be about 400,000 square feet.

The United States Encaustic Tileworks, of Indianapolis (Ind.) and Chicago (Ill.).—This works was established in 1877 by Messrs. Douglas and Hall.

FIG. 142.—Star Encaustic Tileworks, Pittsburg. Erected 1876.

The yearly capacity is estimated to be—of glazed and decorated tile, 1,250,000 square feet; of encaustic and plain tile, 700,000 square feet; of vitreous and ceramic tile, 800,000 square feet; burned with natural gas, which was adopted about twelve years ago.

The Old Bridge Enamelled Brick and Tile Co., of Old Bridge (N.J.), were established in 1889 by Messrs. W. E. Rivers and G. W. Harrison. Their yearly capacity is stated to be of glazed and decorated tiles 625,000 square feet, and of vitreous tiles 200,000 square feet, the fuel used being coal.

The Maywood Art Tile Co., Maywood, New Jersey, are the successors of The Elterich Art Tile Stove Works, which were founded in 1889 by Gustav L. Jaeger and Henry Lindenmeyer for the manufacture of a tile stove, which, however, did not meet with the desired success.

In December 1892 that company was reorganized as a tile factory under the name of Maywood Art Tile Co. by the same people, and Ernst Bilhuber

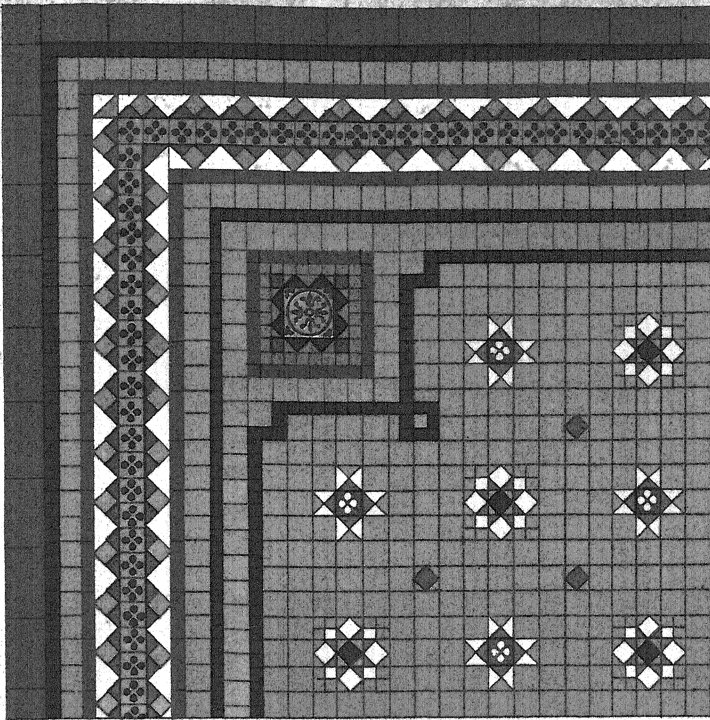
as active partner and manager. The plant is situated along the N.Y.S. and W.R. Railway, whose anthracite coal, egg size, is used as fuel for the kilns. This firm have a capacity for producing 200,000 square feet annually of enamelled tiles, and about 50,000 square feet annually of vitreous floor-tiles.

The Cambridge Tile Manufacturing Co., of Covington (Ky.), state that their plant was established in the year 1887 by A. W. Kock, Heinrich Binz, and F. W. Braunstein. For fuel they use coal, and their yearly capacity in enamelled white wall-tile and decorated tile is about 900,000 square feet, and in vitreous and ceramic tile about 600,000 square feet.

The American Encaustic Tiling Co., Ltd., of Zanesville, Ohio: President, B. Fischer; Vice-President, John Hoge; Treasurer, E. Köhler; Secretary, W. H. Fischer; Superintendent, Geo. A. Stanbery.—This firm apparently have a very extensive works, covering about forty acres, for the manufacture of art, wall, and floor tiles; and have secured gold medals both at Paris in 1900 and at the Pan-American Exposition, 1901. Their New York office is 1123 Broadway. They are said to use local clays mostly, except white clay, which is got from Kentucky. They are reported to have adopted natural gas for fuel only last year.

The Low Art Tile Co., of 34 *Portland Street, Boston (Mass.)*.—These works were originally established in Chelsea (Mass.) in 1879 by John G. Low, Esq., father of one of the present proprietors. The ground area of the present works covers about one and a half acres, and usually about fifty persons are employed. The products are more especially tiles for bathrooms, fireplaces, walls, stoves, and soda-fountains; in addition to these, a novel kind of pottery ware is also manufactured at these works, rather after the style of Japanese ware, which they have named "Low Chelsea ware." The elegant and costly catalogue of copyright æsthetic designs issued by this firm is quite a delight to look through: fancy-shaped tiles first attract the eye, and seem to strike a new vein of decorative wealth; then the profuse variety of low-relief embossed and hand-modelled hearth and wall tiles furnish an even greater selection. Professor C. F. Binns paid this firm an undoubted compliment in the course of the paper, "The Elements of Beauty in Ceramics," read at the Society of Arts, London, 4th April 1894. He said:—"The colours of Bernard Palissy are little more than tinted glazes, and much of their beauty is owing to the fact that they were melted upon a reticulated surface, producing by their flow subtle gradation of light and shade. In modern days this flow of glaze is utilised most successfully by many makers of embossed tiles. . . . Some perfect examples of this style of work have been produced in America by the Low Tile Company, where the effect of skilful modelling is developed by soft tints in glaze." (*Jour. Soc. Arts*, 6th April 1894.)

1 Plate XXIX.



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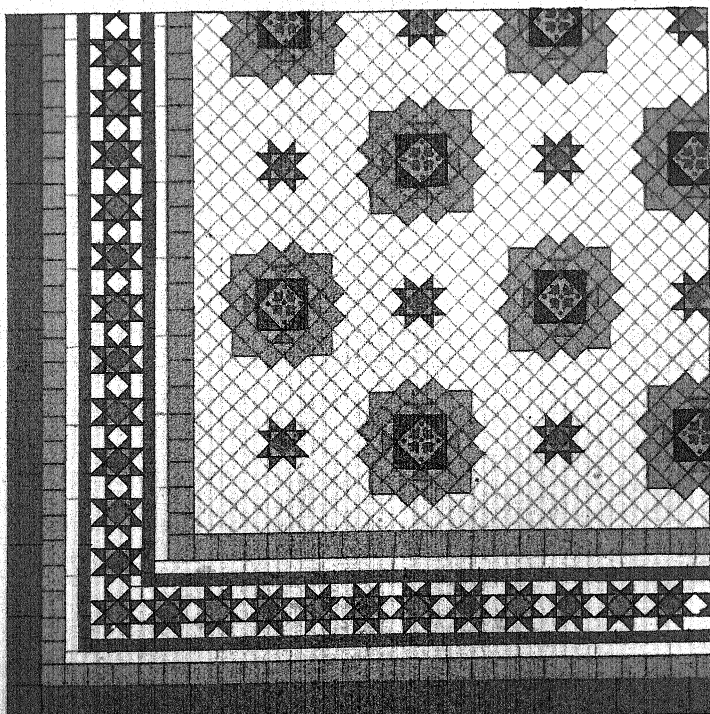


J. Fleming & Co. Lith. Leicester

The Beaver Falls Art Tile Co., Ltd., of Beaver Falls (Pa.), was established in 1887 by Mr. F. W. Walker. This firm appears to devote its attention entirely to glazed and decorated tiles, of which their yearly capacity is about 300,000 square feet. The fuel used is coal.

The Robertson Art Tile Co., of Morrisville (Pa.), is of more recent date, being established in 1890 by Messrs. G. W. Robertson, A. W. Ford, R. K. Bowman, and W. J. J. Bowman. Their plant is said to have a capacity of about 800,000 square feet per annum of glazed and decorated tiles. The fuel used is coal.

The Columbia Encaustic Tile Co., of Anderson (Ind.), U.S.A.: B. O. Haugh (Pres.), G. Lilly (Treas.), H. Haugh (Secy.).—This works was established about thirteen years ago by the present owners, and has a large trade, manufacturing both floor and enamelled tiles. They are said to use mostly local clays, except the white, which is derived from Kentucky. The fuel used is said to be natural gas, which they adopted about twelve years ago.

Other manufacturers in the States, but of which no particulars have been obtained, are:—

The Trent Tile Co., Trenton, N.J.
New Jersey Mosaic Tile Co., Matawan, N.J.
Providential Tileworks Co., Trenton, N.J.
Mosaic Tile Co., Zanesville, Ohio.
H. L. Swift, Riverside, Ia.

Canadian.—The Forsyth Granite and Marble Co., of Montreal (Que.), writing on 22nd May 1903, state that "There are no manufacturers of ceramic or glazed decorative tiles in Canada." The honours, therefore, of the pioneer to this industry in Canada remain open, and his history to some future author. In an attractively illustrated brochure, published by *The Globe* Newspaper Co., of Toronto, "it is said that Canada has more substantial public and private buildings in proportion to its population and development than any other country in the world"; and in the report of the Dominion Department of Trade and Commerce statistics are produced showing that for increase in business Canada "leads the procession" of nations.

The natural sequence of a continuation of this progress will probably be greater extravagance in building decoration, and this will ultimately lead to either some already established brick or terracotta works, or some enterprising company or individual, attempting the production of decorative ceramics in Canada.

In Europe, at the beginning of the nineteenth century, comparatively little was known of the tile trade, yet at the beginning of the twentieth century it

had become a widespread industry. Similarly with Canada, at the beginning of the nineteenth century little was known of it, and the outside world gained their knowledge of it through the flights of fancy of story-writers and artists, who unconsciously created the impression that Canada was a land of almost perpetual winter—an immense wilderness inhabited by Indians and wolves. At the beginning of the twentieth century we have put into our hands this beautiful little booklet, entitled *The Growing Time in Canada*, published at the office of *The Globe*, Toronto, crammed with facts and figures and beautiful photographic illustrations. May not history repeat itself in relation to Canadian ceramics?

One cannot imagine any lack of materials in such a vast domain as Canada, notwithstanding the fact that at present both the Belleville Pottery Co., of Belleville (Ont.), and The Richelieu Pottery Co., of St. John's (Que.), use imported materials. Wood, coal, oil, natural gas, fireclay, ochre, manganese, zinc, ferrous chromite, gypsum, and felspar already figure in Canadian export returns. And there are plenty of clays such as are being used for all kinds of bricks, terracotta, drain-pipes, cement, and common pottery.

In Ontario the "Erie" clay is sometimes sixty feet thick, but is said to contain a considerable quantity of carbonate of lime. The Leda clay, a marine clay overlying boulder clay, found in parts of Ontario and Quebec, burns to a pretty red colour. In Prince Edward Island triassic or upper carboniferous clays and alluvial deposits from these rocks are found; both are said to be red-burning.

These resources and others yet to be discovered, together with the clays associated with the coal-bearing measures of Nova Scotia and British Columbia, may eventually be turned to good use by an enterprising decorative-tile maker some day.

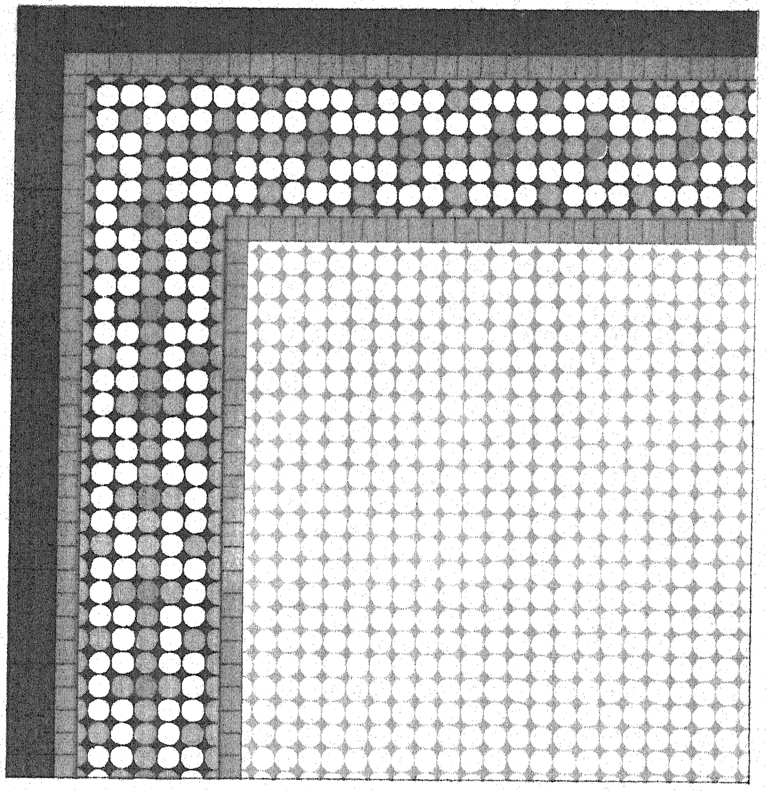
Australian.—With reference to *Victoria*, the acting secretary to the Acting Agent-General has very kindly communicated a few facts collected under the direction of the Secretary of the Department of Mines and Water Supply, Melbourne, and by the assistance of Professor J. D. Gregory.

The firms making decorative tiles are stated to be The Australian Tessellated Tile Co., Ltd., of Mitcham, near Melbourne; and The Brunswick Brick, Tile and Pottery Co., Brunswick.

Several other firms at Brunswick and at Bendigo are engaged in other branches of ceramics; but it is reported that "no faience is made in Victoria." As to materials, kaolin and plastic clays are reported to be widely distributed in Victoria. Strata near Bulla Creek, near Melbourne, and that of a locality near Gordon, are each referred to as containing kaolin.

Plate XXX.

1



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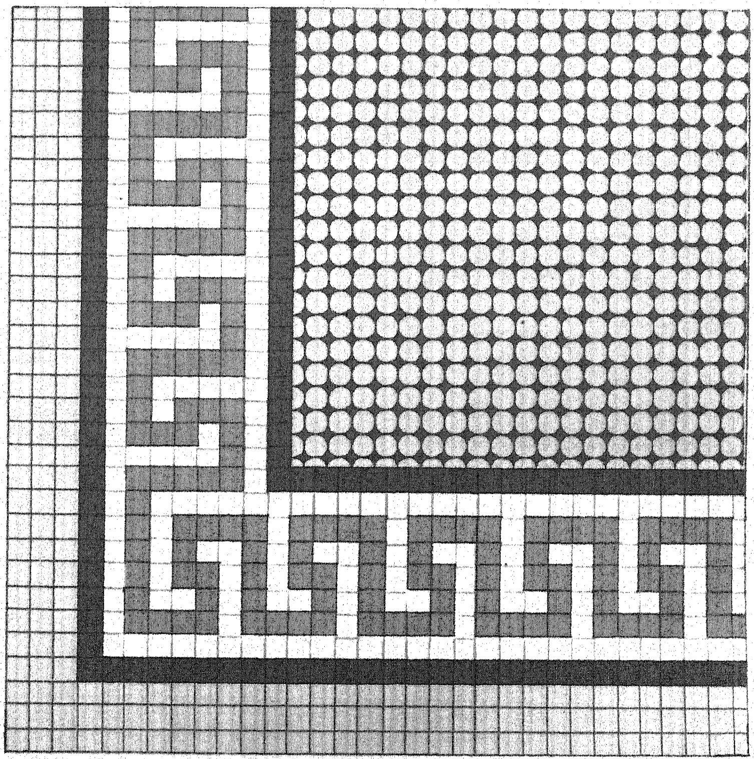


J. FLEMING & Co. LITH. LEICESTER

The following are analyses given of some of the clays found and examined :—

Locality.	SiO_4.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	Combd. H_2O.	Hygroscopic H_2O.	Authority.
Leongattia clay, . .	67·58	17·78	2·58	trace	1·21	1·60	0·28	5·45	2·80	Department laboratory
Horsham white clay, .	60·91	25·60	trace	nil	nil	0·13	0·45	8·11	1·43	,,
Bacchus Marsh clay, .	40·11	37·43	9·29	nil	nil	trace	0·35	13·57	0·40	,,
Murtoa grey-white clay, .	83·13	7·96	1·90	nil	trace	0·21	0·62	5·01	0·90	,,
Traralgon clay, . .	58·78	29·52	nil	trace	trace	1·40	0·63	8·81	1·02	,,
Stawell white clay, . .	62·43	26·01	trace	nil	trace	0·61	0·17	6·90	2·10	,,
Colac clay, ...	68·07	23·87	0·28	nil	trace	trace	1·33	6·39	...	,,

The Stawell clay, upon testing at white heat, yielded a hard white porcelain, and is said to be the best sample of clay submitted.

In New South Wales there are a number of pottery works around Camperdown, Enfield, Petersham, Auburn, and Chatswood. The only firm, however, who, as far as I can ascertain, attempt the manufacture of decorative tiles are Bakewell Bros., of Erskineville, near Sydney. A pottery and brick works has recently been started also at Kuring-gai, near Sydney, where they have shale, red-clay, and pipeclay. (See *Brick and Pottery Trades Journal*, July 1903.)

In the *Annual Report of the Department of Mines and Agriculture of New South Wales, 1891*, pp. 277, 279, Mr. J. C. H. Mingaye, F.C.S., etc., gives analyses of three samples of clay, one of which he pronounces "porcelain clay," and opines that it could be utilized for the manufacture of tiles, ornaments, cups, saucers, etc. The experiments described, however, both on this and the other clays he examined, were evidently conducted in a manner not likely to reveal the real capabilities of the clays. A practical ceramist would probably have produced better results. He adds :—" A large number of fireclays which have come under my notice during the last few years have proved themselves, from experiments made, to be of an excellent quality for the manufacture of firebricks, and some of the clays . . . . proved themselves to be of a very superior quality."

In Queensland, according to Pugh's *Queensland Almanac*, there were in 1902 sixteen pottery works, but no special mention of decorative-tile works appears.

In South Australia the Agent-General kindly gives the names and addresses of ten works, mostly around Maghill, Norwood, Carrondown, Maylands, Woodville, and Tea Tree Gully, but there are none, apparently, devoted to the decorative-tile trade.

In Western Australia large quantities of pipeclay are said to be found distributed all over the colony. In the catalogue of the Colonial and Indian Exhibition of 1886, the local committee for Vasse showed a collection of clays from the neighbourhood of Vasse; also a tile made from clay, presumably local clay, taken from a verandah laid thirty years previously.

At the same exhibition George Whitfield, of Toodyay, showed specimens of pipeclay from Guildford Road, yellow pipeclay from two miles S.E. of Newcastle, and red-clay found in an isolated mass of ironstone three miles from Avon River. Clays were also shown from Phillips' River and from Albany.

To what extent these materials are being economically exploited has not been ascertained.

New Zealand.—New Zealand having been discovered so recently (A.D. 1769), much cannot be expected. However, there are about fourteen pottery works in New Zealand, located mostly in Wellington, Auckland, Avondale, and Sydenham; but the only firm making ornamental floor-tiles and decorative tiles is said to be the New Zealand Potteries Co., at Milton, in the South Island. Messrs. Carder Bros. & Co., of Ponsonby, Auckland, to whom I am indebted for this little piece of news, add that they have had a number of inquiries for these tiles lately.

China.—Ivan Chĕn, of the Chinese Embassy, London, kindly writes that there is a decorative-tile works in Peking, but that tiles are not much used in China for decorative purposes; and that the use of decorative tiles in covering the roof of a building is only allowed to certain princes and ecclesiastical bodies. The Peking tilework is absolutely a native one, and under the superintendence of the Government. Decorative tiles of yellow or green colour are greatly used by privileged persons in covering roofs of their buildings; the use of such tiles in other ways is not restricted, but there is no occasion for it, because of the absence of fireplaces, and other different modes of construction and habits of life render the opportunities for the use of decorative tiles in interiors very limited.

Japan.—Although there are about one hundred and twenty glazed pottery and porcelain works in Japan, and they have at times succeeded in producing wares surpassing in merit those of the Chinese and Koreans, from whom they learned, glazed decorative tiles appear to have been uncalled for, and therefore not much manufactured, in Japan.

Messrs. Mitsui & Co., of London, writing on 27th May 1903, say, "Glazed ornamental tiles are not made in Japan, as there is very little demand for them"; and Messrs. Priest, Marians, & Co., of London, writing on 22nd May 1903, state that "Decorative tiles are not much used in Japan; neither do we think they export these to any great extent."

The latter firm, however, were able to supply the author with four Japanese

tiles of recent production, of Awari make. These each measure about $6\frac{1}{4}$ inches by $6\frac{1}{4}$ inches, or $6\frac{1}{8}$ inches by $6\frac{1}{8}$ inches, by $\frac{1}{2}$-inch thick. Their form and appearance are those of plastic-made tiles, slightly inexact in shape, the body apparently siliceous and of a drab-white colour. Two of these tiles are glazed with a transparent colourless glaze, which has crazed; upon this a ground decoration is stippled and comb-worked; superimposed on this is a floral pattern of imitative style, effected in raised paste enamel of pink and white colours.

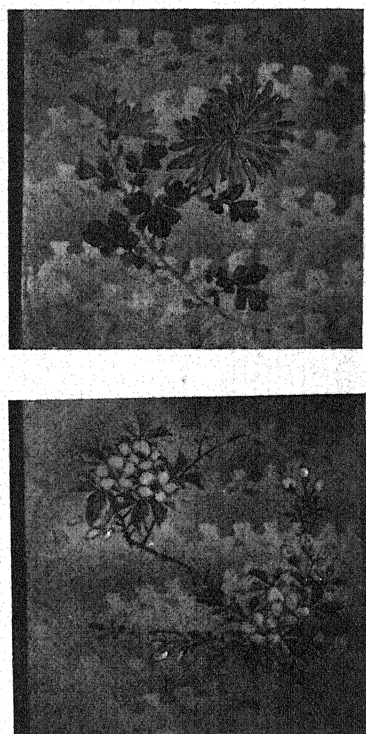


FIG. 143.—Two Japanese tiles. (W.N.F. Coll.)

Two others are glazed with orange-coloured glaze, comb-stippled, and with some brilliant scarlet enamel colour and raised paste decoration, evidently expensive to make, tawdry in effect, and below the requisite standard of accuracy.

No doubt, when the Japanese want to use tiles as Europeans and Americans do, they will very quickly learn to improve their methods and products. Their ability in ceramics is indisputable; and if there is little to record in the particular branch of the art we are considering, the story of their ordinary manufactures of bricks, pottery, and porcelain is highly interesting.

Mr. Ernest Hart, who visited Japan some years ago, gave several instructive lectures on the subject at the Society of Arts, London. From one of these we learn that very early in the nineteenth century great progress had been made in the composition of coloured glazes. It seems that about A.D. 1820 a potter named Zengoro-Hozen, also called Eiraku, developed remarkable skill in this direction, in imitation of the old Cochin-Chinese faiences. "Before long, Zengoro's fame attracted the attention of Harunori, Lord of Kishu. He invited the potter [A.D. 1827] to his province, and there set up for him, within the precincts of the castle park, a kiln, at which was produced the celebrated Oniwa-yaki or Kariaku ware. . . . . Like Luca della Robbia, Zengoro made the composition and application of glazes an especial study. . . . . His Aubergine porcelain, and the rich combinations of turquoise blue, purple, and yellow, shown in the glazes of his faience, amply justify the immense popularity attained by the Yeiraku ware. . . . .

In fact, his coral-red glaze, lustrous and, at the same time, exquisitely soft, with its wealth of golden decoration and reserved medallions in brilliant cobalt, must be classed among the keramic masterpieces, not of Japan alone, but of the whole world. . . . . He had mastered the processes required to produce the purple, yellow, turquoise, and green faience of Cochin-China, the blue and white, coral-red, and enamelled porcelain of China." (*Jour. Soc. Arts*, 26th February 1892, pp. 325, 326.)

Mr. Hart's lecture is a highly instructive and complete *résumé* of the ceramic wares of Japan, worthy of close study by all students of ceramics. He refers also to a work by Captain Brinkley, of Tokio, from whom he most candidly confesses he derived many of the facts. This large work has since been published by Captain Brinkley.

Japanese ornamental brickwork of the nature of architectural terracotta is referred to by a correspondent of *The Brick and Pottery Trades Journal*, April 1904, p. 131; but there are no references to glazed tiles.

CHAPTER IV.

SOURCES AND PREPARATION OF THE CLAYS, MATERIALS, AND COLOURANTS.

FIG. 144.—Clay-mine, N. Devon.

OF the many materials required in the manufacture of decorative tilework, clays, forming, as they do, so large a part of the composition of every piece, appropriately occupy first attention.

Notwithstanding the abundant variety of natural clays, the choice of the manufacturer is limited, his selection being circumscribed by many purely commercial considerations.

Modern facilities of conveyance enable a few fortunate centres, possessing cheap fuel, suitable clays, and skilful artisans, to maintain an enormous output of finished products, and to transport them to any part of the civilized world; and the far-reaching nature of this competition renders it imperative for all makers to attain a fair standard of excellence and attractiveness, to accomplish which the use of superior clays is indispensable.

Recognizing this fundamental principle many years ago, Mr. George Maw, F.G.S., paid special attention to the study of clays, and eventually generously presented to the nation an instructive technical exhibit, which was placed in the Museum of Practical Geology, Jermyn Street, London.

This exhibit comprised a series of trials of clays, together with a valuable commentary thereon. Altogether there were some seven hundred specimens, representing over one hundred and twenty different kinds of clay. These were arranged in geological sequence, and in such a manner that each clay was represented by six specimens, thus:—(1) The native clay; (2) the same

burnt; (3) a slab of unburnt clay, 4 inches by 4 inches, made of the clay after lawning through a 100s-mesh wire lawn; (4) the coarse matter so removed; *i.e.*, the lawn "knockings"; (5) a burnt slab of native or unrefined clay, originally moulded, 4 inches by 4 inches; (6) a burnt slab of the refined clay, also originally moulded, 4 inches by 4 inches.

Mr. Maw observed that some of these clays are semi-indurated, and had to be mined by blasting and brought to the surface in hard rock-like masses, whilst others are soft and plastic when first raised. He also found a great difference in the state of mechanical subdivision of the clays, which is of considerable importance in their applicability to ceramic manufacture; some being almost impalpable, whilst others contain from 10 to 20 per cent. of their weight of coarse refuse. He pointed out four distinct sources of loss and causes of contraction on burning, namely:—(*a*) Water of combination, (*b*) carbonic acid of any carbonates present, (*c*) vegetable and carbonaceous impurities, (*d*) shrinkage arising in the production of vitreous silicates.

He observed, however, that "the amount of contraction is not less due to the state of mechanical subdivision of the constituent particles. Clays in a coarse state . . . . invariably contract less in burning than those of smooth, fine texture." Other interesting information appears in Mr. Maw's report. (*Handbook, Museum Practical Geology*, 1893, p. 20.)

The auxiliary materials used to vary the quality or colour of tile-bodies are principally silica, felspar, china-stone, kaolin, barytes, lime carbonate, and a few mineral and chemical colourants; while glaze ingredients—omitting compounds of lead, arsenic, and antimony—comprise silica in several commercial forms, Cornish china-stone, Jersey china-stone, felspar, kaolin, lime carbonate, barium carbonate, fluor-spar, cryolite, alumina, boracic acid, borax, borate of lime, common salt, soda-ash, soda crystals, nitre, pearlash, magnesia, zinc oxide, white oxide of tin, and many compounds of manganese, iron, copper, cobalt, nickel, chromium, uranium, titanium, platinum, silver, and gold.

The sources and preparation of these different substances will be described, as far as the writer's information and space permit, with the hope that it may save students of ceramics some of the long searches he himself has often experienced in acquiring knowledge of these substances, so often handled by practical potters, yet obtained in such diverse manner.

Before setting out upon the allotted task, however, a few comments upon the value of chemical analysis in connection with these matters may not be out of place, for it has been claimed that, hundreds of years before even the most elementary facts of chemistry were known, certain branches of pottery manufacture had reached a degree of excellence as high as that of to-day. (*British Clayworker*, September 1902, p. 187.)

Brongniart, the world-renowned French ceramist, is said to have recom-

mended the exclusive employment of a certain sand, in preference to another sand, for the preparation of certain fluxes, yet he remarked that the most delicate chemical analysis fails to show any appreciable difference. (*Pottery Gazette*, March 1902, p. 280.)

Geo. F. Harris, F.G.S., has written :—"Two clays of the same chemical composition often behave in a very different manner in the kiln." (*Science of Brickmaking*, p. 36.)

Karl Langenbeck, a most accomplished American ceramist, has written :—"The chemical analysis of clay should be as accurate as possible; yet the very considerable number of slovenly analyses published yearly would seem to make it necessary to insist upon this point. . . . . In spite of the various and detailed descriptions of the treatment of the residue of the acidified fusion of a clay with alkali carbonates, it seems practically impossible to accurately separate silica from the alumina group. . . . . The writer therefore thinks it indispensable to finally obtain the proportion of silica by difference. . . . . It must further be borne in mind that the common impurities of analytical reagents are the normal constituents of clays, and may frequently throw out an accurately manipulated analysis several per cent. . . . . An accurate separation of the clay into its various component minerals is in the present state of analytical knowledge out of the question." (*Chemistry of Pottery*, pp. 3–7, Chem. Pub. Co., Easton, Pa.)

Thus, what with "*slovenly analyses*," estimating "*by difference*," "*common impurities in reagents*," inability to diagnose the "*component minerals*," and acknowledged necessity for final recourse to "*physical tests*," there would appear to be far too much groping in so-called scientific methods at present to warrant the neglect of the time-honoured, less pretentious practical experiment. And while granting chemistry many brilliant triumphs in its own proper field of usefulness, we venture to say that chemical analyses should not be relied upon exclusively, to the neglect of other means of controlling processes of manufacture.

In the study of minerals Rutley observes that "at times a penknife will be more useful than a blowpipe, and a blowpipe than a microscope; at other times a microscope will tell more than a complete chemical analysis." (*Study of Rocks*, p. 5, Longmans.)

Practical ceramists relate similar experience :—"In spite of the time and money spent on countless experiments extending over the past fifty years, clayworkers have to reluctantly admit that there is no known method whereby alkalies may be introduced into a refractory clay in definite quantities, so as to give the same properties as are found in connection with clays that may possess the same amount of alkalies, but occurring naturally." (*British Clayworker*, April 1899, p. 14.)

So that, no matter how intensely a manufacturer may wish to know the

16

deeper truths about his materials, finite understandings and capacity enable us for the present to see these truths but dimly.

Mr. W. Jackson, A.R.C.S., Instructor in Pottery and Porcelain to the Staffordshire County Council, has written :—"The physical properties of . . . . clay are very different, and cannot be predicted with certainty from chemical analysis, and particularly from the old-time ultimate analysis. By this method of investigation one learns the percentages of silica, alumina, lime, etc., in the clay, but nothing of the manner in which these exist. But it is not immaterial how these oxides are present. They may be free or in chemical combination. A high percentage of free silica will endow a clay with very different properties than the same percentage in combination as felspar or as clay substance. It is only when chemical analysis tells us the amounts of the mineral constituents present in the clay that it is of most or often much value. This is the aim of the 'rational' or 'proximate' method of clay analysis, in which it is sought to express the composition in terms of clay substance, quartz, and felspar. Although it cannot be claimed for the method that a high degree of accuracy is attainable, the results are nevertheless of considerable value. A greater insight is afforded into the actual constitution of the clay, and hence prophecy regarding its fusibility, colour, and, to some extent, contraction and plasticity, can be more safely made. Still it is not in this respect that its results are of most value, *for all these properties of a clay can be most easily and surely examined in the actual sample by what may be called* ad hoc *methods.* It is when one seeks to substitute clay for clay, or to imitate an unknown pottery body, that the results are most useful. By a simple calculation, if one has the rational analyses of the clays, it is possible to substitute the one for the other, and obtain, by simultaneous alterations in the felspathic and siliceous contents of the body, identically the same mixture from the chemical standpoint. The new body shall contain exactly the same amount of clay substance, free silica, and felspar as the old. In the same way, having before us the rational analysis of a body it is desired to imitate, and of our raw materials, it is easy to make up a chemically identical mixture. *Unfortunately, however, it does not follow that the same physical properties would be reproduced by these methods. . . . . The necessary alterations to accommodate the new raw materials can only be found by actual trial.*" (*Pottery Gazette*, April 1903, pp. 401, 402.)

Even the apparently simple phenomena of plasticity, colour, and fineness admittedly elude strictly scientific demonstration. Mr. W. Jackson confesses "a most remarkable example of the failure of chemical analysis to reveal physical properties . . . . in the case of the plasticity of clays." (*Pottery Gazette*, April 1903, p. 402.) Yet the difference of plasticity developed merely by different treatment (semi-dry *v.* plastic) has proved so great in brick-making practice as to cause valuable clay-manufacturing plants to be put out of use; and it is said that even "on the plastic system those goods are

infinitely superior where the intricate processes are correctly understood, and the material allowed proper time to accommodate itself to its altered conditions during the transformation from raw material to finished article. . . . ." Continuing the quotation, we read further that ". . . . Nottingham marls were at one time made by the semi-dry process. . . . . Now there is not a semi-dry installation to be found. In France a great wave of semi-dry tilemaking spread through the country; the roofs of France speedily assumed a dilapidated and leaky condition, and now a semi-dry-made tile will not be accepted by anyone. . . . . At Accrington all terracotta work is done on the plastic system, and the results are superb." (*British Clayworker*, July 1903, p. 139.)

This and much more may be said of plasticity, yet chemical analysis fails to reveal the secret.

Again, when referring to the colourant effect of oxide of iron in native clays, Mr. Jackson observes:—"It will be expected that with increasing contents of the staining oxide there will be a continually increasing depth of colour. . . . . This expectation will not be fulfilled. . . . . Not all the peculiar changes of colour which are met with in red clays are produced by the reducing action of oven gases. . . . . These variations are more likely the result of other not yet clearly defined causes." (*Pottery Gazette*, April 1903, p. 406; see also *Trans. American Ceramic Society*, vol. v. pp. 382, 383.)

Then as to the *fineness* of potters' ground materials: when discussing the causes of dissatisfaction with "wet-cylinder" grinding of calcined flint, and the much greater success of "wet-pan" grinding of the same material, Mr. Jackson trenchantly remarks:—"The difference in behaviour between flint ground on the pan and in the cylinder must be due to physical causes. There can be no chemical reason, because the material is identically the same." Yet, in publishing results of a most searching microscopic examination of the product of these two methods of grinding, he writes:—"No difference of shape [of separate particles] could be detected. In fact, unless the photographs were carefully labelled, it were impossible to recognise the one from the other. . . . . There appears to be some subtle difference between the ground material from the pan and that from the cylinder, which so far appears to have escaped detection. It is contended that the cylinder-ground material is lacking in the 'buttery' touch of the pan-ground; it has more tendency to settle out of suspension and form a hard deposit, and the properties of the body compounded from it are such as to lead to excessive loss." (*Pottery Gazette*, May 1903, p. 502; see also *Trans. Am. Cer. Soc.*, vol. v. p. 289.)

In like manner, in connection with other ceramic researches, Professor Edward Orton, jun., of Ohio State University, Colombus, frequently admits unanticipated results in the course of his scientific series of tests, and tells of "complete surprise" (p. 309), "nothing conclusive" (p. 313), "wholly

unsatisfactory" (p. 313), "many contradictions" (p. 322), "analytical results . . . . at fault" (p. 336). (*Trans. Am. Cer. Soc.*, vol. v.)

On the other hand, upon another occasion Mr. Jackson goes so far as to say "the potter's 'rules of thumb' are intensely scientific." (*Staff. Sentinel*, 4th April 1902.)

Dr. S. W. Bushell, C.M.G., M.D., remarks upon the marvellous success of Chinese porcelain manufacture and decoration by "rule of thumb" methods. And Sir C. Purdon Clarke, C.I.E., after speaking of the disastrous results of the introduction of European designs and the British School of Art system in India, comments upon "the great value of workshop lore and *rule of thumb* trade secrets." (*Jour. Soc. Arts*, 18th April 1890.)

Having heard so much in the past of the stupidity and ignorance of practical potters who work by "rule of thumb," this refreshing draught of compliments is really enjoyable. Indeed, one begins to wonder what "rule of thumb" includes! Personally, the writer prefers the term *empirical*, that is to say, a method based upon, and built upon, the results of actual experiment and observation, and comprising all the study and science and art the individual is capable of. This reasonably accounts for the useful, beautiful, and appropriate ceramic wares now being manufactured throughout the civilized world; the finely proportioned and adapted, and the dexterously compounded bodies, glazes, and colours; the skilful processes; and the thousand and one minor contributory matters. It is not haphazard work; it is work guided by experience heaped upon experience, concentrated and handed down from generation to generation, absorbing and assimilating multitudinous useful innovations as they flow in from all sides, scientific or adventitious, like perennial tributaries of a great river of highly specialized hereditary skill; precisely as in the case of every other highly organized and venerable industry.

Nevertheless, just as the plant will not say to the sunshine, "I have no need of thee," neither will the intelligent potter say to the scientist, "I have no need of thee": only, while fully conscious of the limitations of an individual, the practical ceramist realizes his right, if not his necessity, to rely upon empirical tests.

Saggar Marls.—The fireclays, used for firebricks, blocks, and quarries of which decorative-tile makers' kilns are built, and for a variety of oven and kiln appliances, such as bats, setters, cranks, tile-boxes, props, saggars, and the like, are, by British manufacturers, most generally obtained from the upper and middle coal-measures.

In North Staffordshire outcropping strata of the upper coal series and of the upper portion of the middle coal series provide the requisite materials conveniently accessible and near the surface. These fireclays are locally known as "marls," yet the comparative absence of calcium oxide really places

them among the fireclays. Similar strata in other districts are usually called "slender" fireclays, or fireclays of a second class.

The Memoir of the Geological Survey recently published under the title *The Geology of the Country around Stoke-upon-Trent*," contains a detailed and instructive description of the strata in question, and, among other things, includes measured sections of two typical marl-pits, which we reprint below. The first, representing the Cobridge measures, appears to refer to the deepest strata worked for the purpose, those of Hanley being assigned a much higher place in geological sequence.

MARL-PIT NEAR COBRIDGE RAILWAY STATION.

Character of Strata.		Thickness. Ft.	ins.
Black Band Series.	White clay,	5	0
	Limestone,	1	2
	Nodular grey marls,	15	0
	Grey marl,	5	0
	Dark shale,	0	6
	Grey marl,	22	0
	Ironstone, Bassey Mine (*Anthracomya Phillipsi*),	6	0
	Coal, Bassey Mine,	2	0
Upper Portion of Middle Coal-Measures.	Grey marls,	13	0
	Coal, Littlerow,	1	6
	Black shale,	1	6
	Grey marl,	9	0
	Black shale (*Anthracomya Phillipsi*),	0	4
	Grey marl,	10	0
	Grey grit,	1	0
	Grey marl,	17	0
	Peacock coal, just seen,	...	

HAMPTON'S MARL-PIT, HANLEY.

Character of Strata.	Thickness. Ft.	ins.	Character of Strata.	Thickness. Ft.	ins.
Glacial sands and clay,	15	0	Blue, purple, and white clay,	8	6
Stiff white clay with coal streaks,	6	0	Marl,	0	6
Yellow shale with bands of grit,	8	0	Blue and purple marl,	2	0
Black shales (*Anthracomya Phillipsi*),	0	6	Coal smut,	0	2
Yellow shales,	0	8	Grey grit,	1	0
Black shales (*Entomostraca*), fish scales,	0	1½	Yellow shales,	2	6
Grit,	1	0	Black shales with fish scales,	3	0
Mottled red marl,	12	0	Fireclay with plants,	6	0
White clay,	3	0	White marl,	6	0
Coal,	3	3	Grey grit,	0	6
Fireclay,	1	0	White clay with plants,	3	6
White clay (wad clay) and yellow shales,	2	4	Coal,	0	4
Calcareous ironstone,	1	0	Fireclay,	2	0
White clay,	3	0	Coal shales,	2	6
Calcareous ironstone,	1	0	Coal,	3	0
			White marl,	25	0
			Mottled marl,	5	0

(No. 123. *Memoirs of Geological Survey*, p. 42.)

In the abstract of the boring at Newstead, near Trentham, given on pp. 75–81 of the Geological Memoir, thin seams of bass and of coal and beds of fireclay were penetrated at a depth of 557 feet, and again at a depth of 728 feet to 807 feet; but *Bassymine* ironstone was only met with at a depth of 1946 feet 4 inches, below which the section shows thick beds of fireclay and comparatively thin seams of coal down to a depth of 2180 feet.

At George Street, Newcastle-under-Lyme (Staffordshire), the Bassymine coal is said to be about 1300 feet below the surface, and to remain at that level to somewhere near Hanford.

These facts explain why so many potteries are situated as they are, and how it is that fireclay "marl"-pits form an almost continuous line between Longton and Goldenhill, a distance of seven or eight miles, along the line of upheaval and denudation of the coal-measures, on which are found the six large towns—Longton, Fenton, Stoke-upon-Trent, Hanley, Burslem, and Tunstall—constituting "*The Potteries*" district.

In Shropshire, around Broseley, Jackfield, Coalport, and Madeley Market, somewhat similar fireclays from the coal-measures are used for saggar-making, the upper coal-measures being apparently well developed in the Coalbrookdale coalfield.

In Derbyshire and Leicestershire the potters of Woodville, Church Gresley, Swadlincote, and Ashby-de-la-Zouche make use of local fireclays for saggars. These strata, according to Hull's remarks upon the Leicestershire coalfield, appear to belong to the middle and lower coal-measures.

In Chesterfield District, what is called the "Sida" fireclay, from beneath the gannister, together with the very siliceous Brampton brownware clay, from under the coals, are used for saggar-making.

In Yorkshire the far-famed fireclays of the Leeds and Huddersfield portion of the great Notts, Derbyshire, and Yorkshire coalfield furnish abundant saggar-making material.

In Northumberland and Durham the coal-measures furnish the fireclays for saggar-making in the three chief centres of Newcastle-on-Tyne, Gateshead, and Sunderland.

North British potters also make considerable use of clays from the coal-measures and gannister beds for saggar-making. The Glenboig Union Fireclay Co., of Coatbridge, Cumbernauld, and Gartcosh, whose works were originally commenced in 1836, claim to be the largest manufacturers of fireclay in the world, and exhibit a long array of medals for excellence.

Their beds of fireclay are said to be in the millstone-grit formation, and to occur geologically on a horizon 60 fathoms below the Drumgray coal, and 240 fathoms above the Kilsyth coking coal. When used for making saggars, the Glenboig fireclay needs long weathering or exposure, and some admixture of softer clay from more directly under a coal-seam.

Another firm raising excellent saggar clay is that of Messrs. P. & M. Hurll, of Gartlison and Garnqueen, who appear to have secured wide appreciation among stoneware potters, whose requirements must be particularly exacting.

Further north the eminent firm of J. Dougall & Son, of Bonnybridge, raise very serviceable fireclays, from beds below the millstone, for firebricks and saggars. In Kirkcaldy district fireclay from local coal-pits is used for saggars.

Hence it appears that throughout the length and breadth of Great Britain the carboniferous formations are most generally looked to for saggar clays.

In Ireland the only county entered in the *Mines and Quarries Report*, Part III., "Output" statistics for 1901, as raising fireclay is Tyrone; but probably other coalfields of Ireland are capable of yielding clays amenable to treatment for saggar-making.

In a section of "Castlecomer" coal basin, *Peacock* coal, 1 foot 10 inches thick, is entered, with 12 feet of beds above it. And in the "Kilronan" section, 10 to 15 feet of grey soft clay with a roof of coal is shown, and above this clay 24 to 45 feet of white sandstone. (Hull's *Coalfields of Great Britain, etc.*, p. 332.)

In France very different material appears to be used. Brongniart, in his list of saggar clays used at Sèvres, mentions refractory clays from Abondant near Dreux, Condé, Forges-les-Eaux, Moret, Montereau, Le Bretelle, Montigny, Retourneloup, and Provins; and gives elaborate tabulated results indicating the behaviour of these clays in various combinations under fire. The ordinary mixture for saggars was forty parts of clay with sixty parts of crushed old saggars coarsely sieved. With regard to Limoges, Brongniart remarked that the saggar clay used there was obtained from Malaise, near Limoges. (*Traité des Arts Céramiques.*)

At the present time the writer is given to understand that Limoges porcelain-makers obtain saggar clay largely from Poitiers and Berry. In other localities French ceramists obtain refractory clays for saggars from Beaujard near Provins (Seine-et-Marne), Longueville, Montereau, Tavers, Villenauxe, Beaubec-la-Roziere, Moret-sur-Loing, Sully (Oise), Boulogne-sur-Mer, Mussidan (Dordogne), Neuvic-sur-l'Isle (Dordogne), etc.

Nearly all French saggar clays appear to be of tertiary character when not kaolins, and are thus of an entirely different kind from the Staffordshire and other saggar clays of Great Britain, partaking rather of the nature of Devon, Dorset, and Hants clays, except, perhaps, those of Abondant, which, from Brongniart's description, appear to be related to mountain limestone pocket clays.

Hull shows that the upper coal-measures are practically absent in France, but middle coal-measures occur at Alais and St. Etienne, and lower coals at Auchy-au-Bois. There are coalfields also at Therounne, a few miles N.E.

of Boulogne; and anthracite at Isère. From these one would expect fireclays of serviceable quality; although it does not follow that all clays of coal-measures are fireclays.

In Belgium refractory clays—apparently tertiary—occur in the neighbourhood of Andenne, and from this source some of the saggar clays are derived.

Hull mentions a long, narrow coal formation in Belgium, extending from Aix-la-Chapelle westward by Liège, Namur, Mons, and Valenciennes into France.

The writer, however, has not ascertained in what manner and to what extent the clays associated therewith are exploited for the use of ceramists.

In Holland, Messrs. Petrus Regout & Co., of Maestricht, courteously inform the writer that German clays from the Eifel and the Palatinate, and Belgian clays from Andenne, are generally used for saggars; and that the aforenamed clays from Germany are not from coal-pits, but are of tertiary origin.

In Denmark comparatively inferior kaolin, from the island of Bornholm, is said to be used for saggars; and this clay is exported in large quantities to Germany for fireclay purposes.

The Fajancefabrik at Aluminia use the Bornholm clays mixed with English and German fireclays for saggars.

In Germany, Mr. W. Jackson, A.R.C.S., informs me that "the clays used for making saggers in Germany are of three kinds:—

"*a.* Raw china-clays (Roh-kaolinen).

"*b.* Fireclays of shaley character (Steinkohlen-thone).

"*c.* Plastic refractory clays (Braunkohlen-thone).

"The raw china-clays are the naturally occurring heterogeneous mixtures of clay, quartz, and felspathic detritus which constitute china-clay deposits. This material is used in admixture with 'grog' (*chamotte*) and variable quantities of the plastic clays for the sake of tenacity. These mixtures form the saggars for the porcelain industry. The raw china-clays are found in Prussia (near Sennewiz, Saaran, etc.), in Saxony (near Meissen, Aue, etc.), and in Bavaria (near Aschaffenburg), and in many other districts. The shaley fireclays are similar to the clays used for saggers in English factories, and occur in the carboniferous strata of Saarbrucken, in Silesia, Saxony, and Bohemia. The plastic clays are found in strata corresponding with the English miocene beds, and are similar to the Devonshire ball-clays. They occur largely developed on the Rhine near Coblenz, and in many other localities."

Bischop mentions that a certain clay found at Lothain (Saxony) is highly refractory, and particularly prized on that account. He also tells of many other localities where refractory clays are found, mostly of tertiary

origin, such as those of Dunkeritz, Groplitz, Koitsch, Bulsnitz, Waldenburg, Leisnig, Ragowitz, Colditz, Borna, Mehren, Bantzen, Kummersberg, Bornstadt, Lieskan, Rünthal, etc.

In the United States of America the clays used for saggars appear to be partly from cretaceous and tertiary formations of New Jersey and West Tennessee, and partly from coal-measures and upper carboniferous rocks of Maryland, Pennsylvania, Ohio, etc.

Referring to the vast carboniferous formations of North America, aggregating to 229,059 square miles, Hull asserts that its vegetation is at least generically identical with that of Europe, and that the coal-measures, as in England, rest upon a floor of carboniferous limestones, with, in some places, millstone grit intervening. He assumes, therefore, that the age of the coal-fields in both countries is identical. Hence it is reasonable to expect in some localities saggar clays of every grade common to Great Britain.

Langenbeck writes:—"The clays used for yellow-ware belong to the class commercially known as second-class fireclays; the same from which common firebrick and such terracotta articles as stove and flue linings, chimney-pots, garden vases, etc., are made. They are generally the common buff or blue clays of the coal-measures, and are widely distributed in all our carboniferous exposures." (*Chem. of Pottery*, p. 66, Chem. Pub. Co., Easton, Pa.)

Professor Orton, of Ohio State University, writes that the clays of the coal-measures are used in the States for firebrick saggars, tiling, and yellow-ware. The fireclays are found in connection with coal veins, usually directly under coal stratum, though sometimes above it, and sometimes coal replaces it. The buff clays of the Beaver Valley, the flint-clays of Mount Savage and Bolivar are coal-measure clays.

Still, in many cases there seems to be an appreciable difference between our Staffordshire saggar marls and the coal-measure fireclays of the States, for an American manufacturing potter of great experience, who also knows Staffordshire well, assures the writer there are no clays in the States that exactly correspond to what are known as Staffordshire "marls."

What is called the "plastic fireclay" of Mount Savage, Maryland, is an indurated clay of light-grey tint and slightly gritty grain, possessing the hardness and outward appearance of the best siliceous fireclays of Scotland; but a friend, who is intimately acquainted with both classes of fireclay, writes:—"Our plastic clay is similar in appearance to the Lanarkshire clays, but there is a wide difference when burnt. . . . . The plastic fireclays from the coal-measures of this country are all very poor fireclays, and none are in use for the manufacture of the best qualities of firebrick, as they will not stand the fire. . . . . Our plastic clays, however, make excellent building brick, and our enamelled brick are close and dense, absorbing less than 5 per cent. of moisture."

The "flint"-clay of Mount Savage is a highly indurated clay of dark-

drab tint, slate-like hardness, fracturing into sharply angular fragments with keen edges, in some measure resembling the conchoidal fracture of flints. Its general appearance is that of an excessively indurated *cane marl*.

Langenbeck says that "flint-clay" eagerly absorbs water, yielding a mass of shell-like splinters, but that "a year's exposure to weather, while reducing it to a fine sand, fails to produce a workable clay." (*Chem. of Pottery*, p. 69.)

That is to say, it is wanting in plasticity for pot-making purposes. But he points out that these flint-clays are more refractory than the plastic clays which are used as bonds in making fireclay products, and that, as a consequence, firebrick are usually graded into first and second qualities, according to the proportion of flint-clay they contain. (*Ibid.*, p. 170.)

The same author notes that the common idea that all "flint-clays" are highly refractory is nevertheless a mistaken one, for not a few are of low quality.

Mr. Shriver, Mining Superintendent of the Union Mining Company's works at Mount Savage (Md.), informs the writer that their "flint"-clay shows considerable difference in colour in its native state, due to the different amounts of organic matter, the blacker pieces being higher in carbon. He further states that in a heat test the darker pieces show the greatest refractory power, not vitrifying below Seger Cone No. 34.

Another expert in Mount Savage "flint"-clay expresses a belief that it is as refractory as Glenboig clay, but to what extent this has been put to satisfactory and impartial test the writer is not informed.

The two most important states producing fireclays are Pennsylvania and Ohio; for although Maryland took precedence in the discovery of "flint"-clay, Pennsylvania followed soon after by the discovery of similar clay at Bolivar, the industry beginning there about 1838. It has since progressed so fast that Pittsburg now claims the distinction of being one of the leading markets of the world for highly refractory products. According to *Brick*, July 1903, Pennsylvania leads every other state in the union in the matter of firebrick-making.

As to Ohio, Dr. Ries says:—"The fireclays are obtained entirely from the carboniferous, especially the coal-measures. In the lower carboniferous, an important flint-clay is worked at Sciotoville and Portsmouth. In the conglomerate measures, the Tionesta, Upper and Lower Mercer, Sharon, and Quakertown coals are underlain by a seam of fireclay which is worked at Massillon, the Lower Mercer being worked in Stark, Tuscarawas, Hocking, and Muskingum counties. In the lower coal-measures clay underlies the Upper and Lower Freeport, Middle and Lower Kittanning, and Brookville coals. That from the Kittanning far exceeds all the others in value, and is extensively worked" (*Clays of the U.S. East of the*

Mississippi River, p. 66.) In the *Geological Survey Report on the Mineral Resources of U.S., 1901*, Ohio ranks first as a clay-producing and clay-manufacturing state.

Large quantities of saggar clays and other fireclays are also raised in New Jersey State, notwithstanding that, according to Mr. J. C. Smock, Acting State Geologist, there are no coal-measures in New Jersey. Dr. Ries tells us New Jersey now ranks fifth among the clay-producing states, but he

FIG. 145.—Shale-pit near Belleville (Ill.). (*By permission of U.S. Geological Survey.*)

shows by his tabulated list that in 1901 it ranked third. (See p. 166, *Clays of U.S. East of the M. R.*) And in the *Geological Survey Report on the Mineral Resources of the United States, 1901*, New Jersey State is ranked third in this respect.

The principal locality of clay-mining in this state is near Woodbridge, Perth Amboy, and South Amboy, at the mouth of the Raritan River. Owing partly to the quality of the product and partly to the very convenient and easily accessible situation, and its proximity to populous centres, a great industry has been developed.

New Jersey clays, Dr. Ries tells us, not only form the basis of an important local industry, but "large quantities of them are also shipped to neighbouring states, including New York, Connecticut, Massachusetts, Pennsylvania, Maryland, and Ohio."

Dr. Geo. H. Cook, who devoted great attention to these clays, noted some two hundred different kinds, and published in 1878 a most exhaustive report upon them.

For saggar-making it seems that usually the inferior qualities of New Jersey plastic siliceous fireclays are mixed with rather more than equal weight of indurated clays from the carboniferous strata of Maryland, Ohio, or Pennsylvania, such as those of Mount Savage (Md.) and Akron (O.); or with the kaolinique crude clays from Hollisdayburg (Pa.).

Dr. Ries states that the light-grey clay from Mr. Mandle's mines, three miles from Currier, in Western Tennessee, also is shipped to East Liverpool, Ohio, for saggars.

There are also several kinds of clay found within a few miles of Trenton (N.J.), which are said to be used for saggars.

Respecting Illinois, Dr. Ries writes:—"The coal-measure section embraces sixteen seams of coal, No. 1 being the lowest, which are interbedded with a great series of shales, clays, and sandstones. The under-clays are often of a refractory character. Owing to the nearly horizontal position of the beds, mining is usually carried on by shaft, although at several localities, as Galesburg and Belleville [fig. 145], great outcrops of shales occur. The best beds of potter's and fireclays in the state are associated with the lower or No. 1 coal-seam." (*Prof. Paper 11*, p. 95.)

SAGGAR AND SETTER MARL MIXTURES.—In the actual use of these clays and "marls" in Staffordshire, employers and operatives acquire individual preferences both as to quality of "marl" or clay, and proportion of "sherds," "grog," pitchers, or sandstone to be intermixed; hence no hard and fast rule can be laid down. Indeed, one firm of marl-getters state that they have twenty different ways of preparing such compositions to enable them to satisfy their clients. In the first place, the mixture must possess special suitability for the appliance to be formed of it; for instance, firebricks, fireclay-quarries, saggars, boxes, setters, each need specially compounded mixtures.

In Simeon Shaw's time (1837) the compound for potter's saggars was usually

50 parts of grey marl,
25 ,, ,, black marl,
25 ,, ,, ground saggars,

and by careful selection of the "marls" or slender fireclays in question it is probable that such a compound would answer the purpose to-day; but ideal

mixtures for the preparation of saggars, of greatest practicable wearing power, would, we are informed, be approximately as under :—

Marl Mixtures.	For Saggar Sides.	For Saggar Bottoms.
"Peacock" marl or fireclay,	4 barrowfuls	4 barrowfuls.
"Littlerow" ,, ,,	2 ,,	2 ,,
"Bassymine" cane marl,	1 ,,	1 ,,
Broken biscuit-oven saggars,	3 ,,	6 ,,

the above ground together through perforated grids in the pan of a powerful edge-runner mill, the holes ranging from one-eighth of an inch to three-eighths of an inch, and the grids being frequently replaced as the mesh wears larger; the ground compound then well tempered with water, soaked, and pugged.

But ideal mixtures are not always convenient; the necessary proportion of siliceous marl, such as Peacock marl, may not be available, or the operative saggar-maker may prefer more plastic marls; consequently, more representative mixtures of what is now in use are as under :—

Side Marl Mixture for Saggars.

2	barrowfuls	"Peacock" marl or fireclay	or similar marls or fireclays
3	,,	"Littlerow" ,, ,,	
4	,,	"Bassymine" or cane marl	
6	,,	broken saggars	

Bottom Marl Mixture for Saggars.

2	barrowfuls	"Peacock" marl or fireclay	or similar marls or fireclays
3	,,	"Littlerow" ,, ,,	
4	,,	"Bassymine" or cane marl	
9	,,	broken saggars	

ground through perforated grids in an edge-runner mill $\frac{1}{8}$-inch to $\frac{3}{8}$-inch mesh, then tempered, soaked, and pugged.

Mixture for Fire Quarries and Setters.

18	barrowfuls	Peacock marl or fireclay.
6	,,	broken biscuit pitchers.
1	,,	sandstone (preferably calcined).

Where Peacock marl is not available, a rather coarsely siliceous marl may take its place, if refractory.

The mixture being formed as above, it is all ground together, well tempered, longsoaked, and pugged. But the proportion of pitchers and sandstone must be varied according to the condition and quality of the marl. A strong fire-resisting marl, needing less of both pitchers and sandstone, or possibly no sandstone, may be desirable. On the other hand, if a more plastic or cane marl is used, then considerably more of pitchers and of sandstone may have to be introduced to secure good results.

MIXTURE FOR CRANKS OR BOXES.

7 barrowfuls cleanest weathered "Peacock marl" (fireclay).
3 ,, pulverized biscuit white earthenware pitchers.
1 ,, ground sandstone (millstone grit or gannister).

To be ground together in a solid-bottomed pan, edge-runner mill, and screened through sieves $\frac{1}{10}$-inch mesh; then soaked fourteen days, during which it is turned over a number of times, and then pugged through a slow-working pug-mill with small orifice.

ANOTHER SETTER-CLAY MIXTURE.

2 parts ball-clay.
2 ,, saggar clay (fireclay).
2 ,, fine grog, *i.e.*, crushed saggars.
1 ,, sand (preferably calcined).

In selecting marls or fireclays for any of the foregoing mixtures, it is desirable to avoid as far as practicable contamination by fragments of the shales and ironstone occurring in contiguous strata; also the nodular concretions often found in the marl itself; because such impurities may boil up, blister, blacken, or fly off and strike upon the wares during burning. Some of the Staffordshire slender fireclays are impregnated by very deleterious concretionary substances of this character, and these must be carefully picked out.

Respecting the influence of grog in saggar-marl mixtures, a very interesting series of experiments and observations are recorded in *Trans. N.S. Ceramic Society*, vol. ii. pp. 14–25.

Researches were made as to the comparative effect of proportion of mixtures of 5 parts marl with 1 part grog, and 5 parts marl with 3 parts grog; also as to the comparative effect of using grog of different degrees of coarseness, namely:—(*a*) Grog that passed through a 4^s sieve, but was retained by a 10^s sieve; (*b*) passed through 10^s sieve, but retained by 16^s sieve; (*c*) passed 16^s sieve, retained by 40^s sieve; (*d*) passed through 40^s sieve.

Results of these researches were carefully tabulated, and the ascertained relative contraction, porosity, tensile strength, and behaviour upon heating and cooling systematically recorded, both after "earthenware" firing and "china" firing.

Summing up results, Messrs. H. W. Edwards and A. Leese, who conducted these experiments under the supervision of Mr. W. Jackson, A.R.C.S., at Sutherland Institute, Longton, state their conclusions thus:—

"*Effects of increasing the size of grog.*

"(1) No regular effect on contraction.

"(2) Decreases strength both in the green and fired states.

"(3) The largest grog greatly increases resistance to fracture by sudden temperature changes.
"(4) Increases porosity.

"*Effects of an increasing proportion of grog.*

"(1) Decreases contraction.
"(2) Decreases strength both in the green and fired states.
"(3) No effect on resistance to temperature changes.
"(4) Increases porosity.

"From a practical point of view, we see that the two principal properties of saggars, viz., tensile strength and resistance to temperature changes, would be inversely altered by using larger or smaller grog—leaving out the fine dust—and THE BEST MIXTURE FOR ALL PURPOSES CAN ONLY BE ASCERTAINED BY PRACTICAL EXPERIMENT ON A LARGE SCALE."

From the interesting discussion that followed upon the reading of the aforenamed record of researches, it is possible to glean some useful matter. For instance, Mr. A. Heath related a personal experience in the matter of losses of "setters" or "cranks" in the manufacture of chinaware, and explained that the loss had been brought down from twenty dozens per oven to not more than one and a half dozens per oven, by substituting crushed "china" pitchers for grog in the mixture of which the "setters" or "cranks" were made. In grinding the china pitchers all sizes greater than would pass through a 6^s sieve were discarded. Thus the composition became one of marl (fireclay) and china pitchers, instead of marl (fireclay) and grog (burnt saggars).

Commenting upon the above incident, the chairman, Mr. Henry Watkin, observed that "The results were the same as some obtained by himself some years ago, when he found a mixture of china-clay and best white earthenware biscuit pitchers gave a body capable of withstanding a temperature sufficient to fuse china, and excessively rapid temperature change. There was an enormous waste of best white pitchers, while the common broken saggars were utilised. It appeared to him that the wrong material was being wasted. . . . . It was his opinion that for the improvement of our saggars we must look more and more to the biscuit pitchers and less and less to grog." (*Trans. North Staff. Ceramic Soc.*, vol. ii. p. 29.)

The wearing power or "life" of saggars and fireclay appliances in general is an item of considerable importance economically on a decorative-tile works. The burning question of the firebrick trade, as to the comparative values of machine-made semi-dry and of hand-made or "slop" firebrick, finds a counterpart in the diversity of opinion respecting fireclay apparatus of the more varied kind used by potters. Scientific tests for refractoriness do not of themselves take into account all the practical considerations depending upon relative cohesion during incandescence and when cold; consequently,

ordinary industrial and empirical tests are necessary: for, as Langenbeck aptly expresses it, "The loss the potter fears in his saggars is not from fusing, but from cracking. Their walls, compared with brick, are comparatively thin, and, being filled with ware and piled in 'bungs' to the height of 15 feet and more, often have to bear considerable weight. While a brick, forming part of a solid wall . . . . presents but one front to the fire, saggars are surrounded with the fire gases, and, upon cessation of the fire, with the strong draught of the cooling air. . . . . A saggar made of clay burning dense at the heat of the kiln will not remain intact under such conditions." (*Chemistry of Pottery*, p. 164.)

Considering the fluxing tendencies of alkalies, alkaline earths, and oxides of iron, when brought into intimate contact with silica or silicates and subjected to high temperatures, one would have expected chemical analysis to have been of greater value than it actually proves to be. According to James Dunnachie, of Glenboig, a most experienced and successful North British fireclay goods manufacturer, "Chemical analysis does not reveal all that is necessary to enable us to form a correct estimate of the characteristics of a firebrick and its suitability for certain kinds of furnaces; much depends on the physical structure and arrangement of the particles composing it, as well as upon other peculiarities consequent upon the mode of manufacture. We often find that two kinds of firebricks, made from clays apparently identical in chemical composition, differ widely in their refractory qualities." (From the *Engineering Magazine*, reprinted in *British Clayworker*, February 1899, p. 321.)

Similar opinion, expressed at much greater length, and arising from a wholly distinct set of experiences with fireclays worked in the United States of America, is recorded in the *British Clayworker*, December 1896, p. 213. This observer ventured to say:—"We can take the very best clay . . . . and by improper manufacture produce an inferior brick to one made out of poorer clay, but treated to make the best out of it. This does not say, of course, that a brick of the highest class can be made out of bad clay." (*B.C.W.*, December 1896.)

Again, Langenbeck asserts, even more positively, that "to value a clay directly and solely by its 'oxygen ratio' calculated from the analysis, so commonly taught the public by chemists . . . . is, to say the least, misleading. All that this ratio is supposed to teach—the relative fusibilities of clays—is more expeditiously and accurately determined by direct fusion . . . . for the structure of a clay plays quite as important a part in its fusibility as its chemical composition." (*Chemistry of Pottery*, p. 164.)

To attempt to specify chemical desiderata where requirements differ so much, and where long practical experience so strongly emphasises the fact that physical condition exercises such a potent influence, would appear

superfluous; nevertheless, for what they are worth, a number of chemical analyses of representative fireclays, saggar marls, and the like are appended.

TABLE OF ANALYSES OF FIRECLAYS AND SAGGAR MARLS.

Material.	SiO_2.	Al_2O_3.	FeO and Fe_2O_3.	TiO.	CaO.	MgO.	Ca. Phos.	Alk.	Organic and Loss.	Combined Water.	Moisture.	Analyst or Authority.
"Peacock" fireclay, .	63·83	25·75	1·35	0·93	...	0·56	...	...	...	7·99	...	Bowes & Sims, 1904.
"Bassymine" marl, . .	63·38	21·01	3·16	0·24	0·52	0·95	trace	3·22	...	8·01	...	J. Lones, 1904.
Sneyd marl, . . .	76·29	16·32	1·85	...	trace	...	trace	...	5·67		...	T. Blackshaw, 1885.
Hanley saggar marl, . .	62·10	28·72	3·28	...	0·85	0·21	...	...	4·84	...	...	A. Catchu, 1887.
,, quarry marl, . .	57·25	36·15	1·95	...	1·34	0·21	...	...	...	...	3·10	A. Catchu, 1887.
Stourbridge fireclay, . .	72·51	20·26	3·30	...	0·89	1·48	1·53	...	...	...	...	
,, ,, . .	63·40	31·70	3·00	...	...	...	...		1·90		...	Prof. Abel.
,, ,, . .	65·10	22·22	1·92	...	0·14	0·18	{ P_2O_3 0·06 }	0·18	0·58	7·10	2·18	Mus. Pract. Geol.
Leeds fireclay, . . .	70·55	20·27	1·45	...	0·75	0·24	...	...	0·22	6·52	...	Ansell.
,, tender fireclay, .	64·92	25·53	2·14	...	0·33	...	...	0·50	6·71		...	Ansell.
Shibden (Halifax) fireclay,	79·60	18·21	0·52	...	0·54	0·43	...	0·69	...	...	...	Ansell.
Blaydon Burn fireclay, .	69·25	17·90	2·97	...	1·30		...	...		7·50		
Glenboig fireclay, . .	62·50	34·00	2·70	...	...	...	...	...	0·80	...	...	Prof. Abel.
Star Glenboig fireclay, calcined, ...	65·41	30·55	1·70	1·33	0·69	0·64	...	0·65	...	...	...	E. Riley, 1875.
Gartcosh fireclay, calcined,	61·90	32·34	3·02	2·09	0·37	0·20	...	0·36	...	...	...	W. Wallace.
Gartlison or Garnqueen, .	56·70	38·52	2·15	0·76	0·80	0·19	...	0·88	...	...	...	Tatlock & Co.
Bonnyside white gannister, calcined, . . .	95·50	3·38	0·05	0·36	0·45	trace	...	0·26	...	...	...	Tatlock & Co.
Bonnyside fireclay, calcined, ...	55·70	39·62	2·00	0·92	0·61	0·45	...	0·70	...	...	...	Tatlock & Co.
Bonnyside firebrick, .	66·20	29·09	3·21	...	0·54	0·40	...	0·56	...	...	...	W. R. Hutton.
Abondant (France), . .	50·60	35·20	0·40	...	...	...	...	...	...	13·10	...	Brongniart.
Retourneloup (France), .	42·00	38·96	0·85	...	1·04	0·17	...	trace	...	16·96	2·27	Brongniart.
Neuvic (France), . .	47·80	36·90	1·70	...	...	trace	...	...	...	13·10	...	Russey.
Palatina X firebrick (German), ...	54·22	42·90	1·67	...	0·36	0·11	...	1·13	...	...	...	Pfälzische Co.
Bornholm clay (Denmark),	72·50	19·50	1·00	...	0·18	0·50	...	...	...	5·92	0·27	Brongniart.
Delaware saggar clay, .	72·33	16·75	1·29	...	2·00	0·07	...	...	...	6·84	1·14	
Bolivar (Pa.) clay, average,	52·23	26·03	1·29	0·49	0·33	0·13	...	0·62	...	11·15	..	Reese Hammond.
,, "flint"-clay, .	50·84	30·74	3·21	1·26	0·16	0·28	...	0·54	...	13·5	...	
,, ,, ,, .	43·46	26·39	1·03	...	0·08	0·24	...	...	...	13·29	...	
,, plastic clay, . .	59·83	24·58	1·65	1·17	0·28	0·87	...	3·11	...	7·83	...	
Mt. Savage (Md.) clay, .	44·40	38·56	1·08	...	...	0·11	...	0·25	...	14·57	...	S. S. Hartranft.
,, ,, ,, .	56·80	30·80	1·12	...	...	...	...	0·80	...	10·50	...	Dr. G. H. Cook.
Woodbridge (N.J.) clay, .	44·90	38·24	0·96	1·80	trace	0·11	...	0·15	...	14·10	0·70	Dr. G. H. Cook.
,, sandy clay, .	71·80	18·92	0·88	...	...	...	...	0·48	...	6·70	0·50	Dr. G. H. Cook.
Beaver Valley (Pa.) (buff clay), ...	61·97	22·94	1·81	1·97	0·44	0·52	...	1·75	...	7·37	1·48	
New Brighton (Pa.), .	60·14	26·64	2·64	...	0·51	0·29	...	...	9·66	...	...	

Buff or Cane Marls.—The term "can" marl often appears in quaint old Staffordshire recipes, and local custom must again excuse us for referring to these slender fireclays as marls, though the percentage of calcium compounds is practically only a mere trace. Staffordshire cane marls are the selected, cleanest, finest, most plastic grey marls or slender fireclays of the upper coal-measures, mostly of the Black Band series, and preferably perhaps the lower Bassymine marl; but the Littlerow seam and the Upper Peacock marl may occasionally yield useful cane marls for certain purposes. In the numerous seams above the Bassymine, comprising the Black Band series, a great variety occur; each seam having its own peculiarities only to be learned by experiment or by manufacturing practice. They are raised at Tunstall, Cobridge, Hanley, and Fenton in North Staffordshire, and somewhat similar marls are raised in South Staffordshire, and in parts of the Derbyshire, Shropshire, and Yorkshire coalfields.

In every instance only special seams are taken, and great care exercised in selection, for there are bad sections in most seams that must be avoided. The very dark-grey or black marls often prove sticky rather than plastic, and preference should be given to the light-grey marls where these possess the necessary qualities of colour, fineness, and freedom from specks. For the purposes of the decorative-tile maker such "marls" should not be milled in any way, but should be taken direct from the marl-pit to weathering grounds, and there spread out in shallow heaps and exposed to weather for some months; during this time they must be occasionally turned over, and any nodules or detritus of a foreign nature carefully picked off. When extensive weathering yards are not available, the slipmakers should skim off only the upper layers of the marl-heaps as required from time to time.

In certain districts in Germany similar clays from the coal-measures are said to be used for tiles and architectural terracotta. Mr. Jackson states that they closely resemble English carboniferous fireclays applied to similar purposes, and burn to many shades of colour from almost white.

In Belgium a clay burning to a remarkably pretty cane colour or light-yellowish buff colour is raised near Andenne.

In the United States excellent buff-burning clays are obtained in Beaver Valley district, Pennsylvania, and near East Liverpool, Ohio. And the eminent American ceramist Langenbeck observes that some of the "flint"-clays, if specially prepared, are serviceable for such purposes as are under consideration, but that they have been barred by physical characteristics. (See *Chemistry of Pottery*, pp. 68–70.)

In the choice of these clays, preference should be given to such as retain a good and even colour when burned, are as free as practicable from specks, do not "cut" or crack, are not excessively refractory, and are of fine smooth grain. This bouquet of desiderata may not always be attainable; yet

remarkably excellent cane "marls" or slender fireclays exist, and only need seeking out and proper selection and treatment.

But the rich cane-yellow colour of a "marl" may sometimes be much impaired by a tendency to become variously tinted when burned; possibly this arises from the presence of a soluble colourant which is drawn to the surface during drying or burning.

At other times it is not improbable that the defect is induced by careless or unsuitable burning. Professor E. Orton, of Ohio State University, in his paper on "The Rôle of Iron in Clay-burning," remarks upon flashing thus:—"It has been shown that where a clay is frequently subjected to alternate oxidizing and reducing conditions, that it shows a change in colour, which is superficial if the ware is vitrified and dense, and entire when the ware is porous. This colour is that produced by ferric oxide, only darker and stronger. In a buff clay it is golden, russet, or brown. In a red clay it is chocolate or almost black. It has been shown that this colour cannot be developed by a continuously oxidizing burn. It requires reduction, followed by oxidation, to develop it. The more times this change occurs, the more brilliant the colour, and the easier it is to develop. It also requires that the reoxidation shall be as well marked as the reduction." (*Trans. Am. C.S.*, vol. v. p. 425.)

In the course of the same interesting paper, Professor Orton further observed that "Buff-burning clays do not burn buff because of the exact amount of iron they contain. Often they might either burn red or white, so far as the iron content is concerned. Obviously, quantity alone is a less perfect explanation for this group than for either of the others. . . . . Suffice it to say that there are certainly two sorts of buff-burning clays with different histories, and whose colour proceeds from different causes. In both, the colour is thought to be due to the chemical influence of other elements on the iron oxide." (*Trans. Am. Cer. Soc.*, vol. v. p. 381.)

In England, however, three varieties of buff-burning clays present themselves in nature, viz., clays of the coal-measures, which burn to a cane-tinted buff; clays of the tertiary formations of Devon and Dorset, which burn to a rather dull buff; and clays of the calcareous ferruginous class, whose tint when burned may be very irregular and uncertain.

It is unnecessary to discuss these individually in this paragraph, but it may be well just to record the impression that titanic acid in some chemical association with iron may have to do with the colour of best cane clays.

Red Marls and Clays.—Clays that assume a lively red colour upon suitable preparation and suitable burning, although often of a red colour in their native state, are not necessarily so; they may, indeed, be either red, dull purple-red, red-brown, yellow, or grey. Such clays are widely distributed geologically, and extensively used for making bricks, terracotta, and common red pottery.

But only a comparatively limited number of these will answer the purpose of ornamental floor-tile makers. By reason of the high standard of quality, colour, grain, and durability now ruling, the choice is circumscribed, not so much perhaps to particular strata, as to particular results, which are found to be most economically and satisfactorily attained by the use of certain strata.

The red clays—often, incorrectly perhaps, called red marls—used for the purpose in Staffordshire are specially selected beds found in rather promiscuous positions among the upper coal-measures. Until recently many of the local red clays or marls of North Staffordshire were classed by geologists as "*Permian*" (see Hull's *Coalfields of Great Britain*, p. 182); but this view has been relinquished, and an explanation of the reasons for the change of classification is given in the *Memoir of the Geological Survey of the Country around Stoke-on-Trent*, recently published.

They are now known as the "Etruria Marl Series" of the upper coal-measures; but the Memoir does not clearly indicate the geological character of those superior portions used by ornamental floor-tile makers, therefore sections are not repeated here.

In North Staffordshire red clays or "marls" for commoner purposes are raised around Madeley Heath, Bradwell Wood, Newcastle-under-Lyme, Hartshill, Penkhull, Stoke-on-Trent, Fenton, Trent Vale, Hanford, Blurton, Cocknage, and Cophurst; and from among these the very best only are used by ornamental floor-tile makers, supplemented by other clays found around Wetley Moor, Wetley Rocks, Thornyedge, Cellarhead, Froghall, and Mow Cop. Perhaps the most highly esteemed red floor-tile clay in North Staffordshire is a comparatively small bed laying near the junction of the trias sandstone with the Etruria marls at Cophurst, near Longton. In Shropshire and in North Wales suitable clay is found around Broseley, Jackfield, Ironbridge, Madeley Wood, Sweeney, Penybont, Hafod, Afongoch, Ruabon, and Wrexham.

In the south of England red tile-clay is found at Corfe Mullen and at Fareham, but of unascertained geological position. In Lancashire the Accrington red-burning shale appears susceptible of treatment for tilemaking, but the writer is not cognisant of it being so utilized. In Ireland, according to the report by Mr. Rix, red clays are found in Co. Cork, Co. Limerick, Co. Antrim, Co. Down, Co. Leitrim, Co. Wicklow, Co. Meath, Co. Tipperary, and Co. Wexford. Possibly some of these would furnish suitable clays.

In France, good red tile-clay is found at St. André, near Marseilles, and probably there are many other sources.

In Spain red clays occur at La Brisba near Gerona, Barcelona, Tarragona, San Saturnino de Noya, and Valence.

In the United States excellent red floor-tile clay is found at Pittsburg, Pa., and probably also at Zanesville, Ohio, the locale of the American Encaustic Tiling Co. Mr. W. G. Worcester, of Parkersburg (W. Va.), highly commends the

Bedford shale found at Cleveland (Ohio) for the manufacture of red flooring-tiles. He claims that it produces on burning one of the most magnificent red colours known, probably the finest red colour of any clay in the United States; and that it possesses the property of vitrifying at a low and safe rate, because its point of vitrification and its melting-point are separated by a wide interval. Further, it retains its fine red colour even when vitrified. This red colour owes its source to the presence of finely divided ferric oxide, already indicated by the chocolate colour of the shale. It is, he says, extremely fine grained, and is readily made up to a plastic body. It has, however, a large shrinkage, and must be burned slowly. It is found at South Park, Elyria, Brownhelm, Cleveland; also at several places in Crawford County and Delaware County, and from the latter has been traced uninterruptedly for fifteen miles southward. (*Trans. A.C.S.*, vol. v. p. 296.)

Preparation.—The first essential in every case is to exercise utmost vigilance over the selection, so that only those particular portions of the seams or deposits are made use of which, when burned, are of a sufficiently red colour and sufficiently cohesive and durable.

Many red marls of the "Etruria" and other series are of too poor colour when burnt; others too porous and weak; others, again, contain particles which develop into black or white or cane-coloured specks in the finished tile. A few red clays have excessively vitreous and plastic qualities, and have to be used discreetly in association with less vitreous ones, or with kaolin; hence, the importance of care in primary selection and separation from contiguous strata. Then, many of these red clays or marls are of an indurated nature, rock-like, almost stony, in the native state; and these have to be laid in low heaps on extensive weathering grounds and exposed to the elements, the effect being accelerated by occasional turning over of the heaps by spade, in the course of which foreign detritus should be rigorously picked out.

Properties.—Good clays for red floor-tiles and tesseræ, when burned at a temperature and under conditions that ensure soundness of the product, should develop a full red colour inclining toward a crimson shade, free from scum, specks, and blisters, and with the least possible twisting, buckling, cutting, or cracking.

Clays, experimentally found to possess most of the required qualities, but yielding tiles too large or too small in size, may be brought into use by intermixing with clays of opposite quality that will compensate the defects. And as most red bodies for ornamental floor-tiles are prepared by refining in the "slip" state, the additional expense of intimate intermixing of several clays is small.

It does not follow, however, that clays capable of producing pretty terracotta will answer the purpose of floor-tiles, for terracotta clays may, in some

cases, mature in colour at so low a heat as to leave the product too weak for tiles.

The essential colourant is sesqui-oxide of iron—Fe_2O_3—which under certain conditions acquires and imparts to the ware a tolerably bright shade of red. But to attain a good red tint other things are essential; for instance, the almost total absence of other colourant oxides, and, in a measure, also of alkalies and alkaline earths.

Maw found that 5 per cent. of caustic magnesia, when added to and intimately mixed with some red-burning clays, destroyed the red colour on calcination; and it is well known that excess of alkali, by promoting chemical combination and easy fusibility of the mass, influences the colour very detrimentally.

With regard to colour-development, Professor E. Orton states that "The red colour of red-burning clays is not in proportion to the iron contents. . . . . Many clay containing 4 or 5 per cent. of ferric oxide burns as fine a red colour as others containing 7 or 8. . . . . The distribution seems more important than the amount. While we do not find clays burning red without some considerable iron in their make-up, we do not find all clays burning red which contain this amount of iron." (*Trans. Am. Cer. Soc.*, vol. v. p. 381.)

Further, Professor E. Orton remarks that "A red-burning clay which has been properly treated in the burn up to 900° C. has acquired by that time a yellowish-red or pale-red colour, which is called salmon. As the temperature continues to rise, this colour deepens and brightens, until by 1100° C. in most clays it attains its maximum brilliance and power. This red colour is said to be that of free ferric oxide, which covers the grains of the other minerals with a film, and creates almost as much colour and as bright a tint as if the mass were ferric oxide throughout. . . . . The evidence that proves this to be the ferric oxide and not a ferric silicate or aluminate is more negative than positive, however. . . . . The question now arises, why is it that ferric oxide can remain so long out of combination, when surrounded by clay silica and other fluxing minerals, which are one by one breaking down and entering into bonds with one another? The question must remain unanswered. But experience proves that, whatever the red colour is, it remains intact for a long time as the heat rises, suffering no change, except a gradual brightening and deepening of tint, up to a certain maximum. This maximum is not a fixed point for all clays. It varies with the composition of each. Those clays which keep it the longest are those containing least clay substance and most pure sand. A very sandy clay from Wisconsin was fired by the writer to Cone 8, in a not very oxidizing burn, and remained a fine strong red, bordering on purple, at this temperature. An ordinary red clay containing 50 per cent. clay substance cannot be fired above Cone 1 without beginning

to show a decline. Soft fluxes like lead or alkalies, which promote silicate formation, tend to bring the iron into combination also, and destroy the red colour of ferric oxide.

"As a rule, the retention of the red colour in its perfection, and the development of a close, dense, glass-like vitrification, seem to be mutually antipathetic conditions. That is, in most red-burning clays their behaviour seems clearly to bear out the contention that the colour is due to free iron; for as fast as the vitrification becomes visibly more perfect, the colour darkens and the body seems to approach to its point of breaking down.

"But occasionally, or rarely, a clay is met which contradicts this impression. Such clays have, in the writer's experience, attained a vitrification almost like glass, preserving the while a red as bright and beautiful as sealing-wax. Ink placed on the fracture will dry and scale off without leaving a mark.

"It is truly hard to see how iron can be wholly free and unattached in a silicate mass of such perfection. But when such a clay is heated past this culminating point, it follows the general law, and blackens as it breaks down, thus seeming to show that combination of the iron means loss of its ferric character. . . . . A *résumé* of the evidence, then, seems to indicate that clays are coloured red by free ferric oxide, and that combination of iron with clay or silica involves blackening and formation of the ferrous silicate." (*Trans. American Ceramic Society*, vol. v. pp. 413–415.)

ANALYSES OF RED CLAYS AND MARLS.

Source.	SiO_2.	Al_2O_3.	FeO.	Fe_2O_3.	CaO.	MgO.	TiO.	Alk.	Organic and Loss.	Combined Water.	Moisture.	Analyst or Authority.
Longport, . .	54·50	16·50	...	13·50	3·37	...	...	...	...	10·60	1·40	Salvetat.
Cophurst,* . .	85·35	7·80	...	5·20	0·35	traces	...	1·30		...	1·20	J. Baynes, F.I.C.
Ruabon, . .	63·0	20·10	1·51	4·84	...	...	...	5·47	..	3·54	1·54	G. F. Harris, F.G.S.
Watcombe, . .	57·83	20·35	...	7·75	1·68	0·97	...	4·43	...	4·39	2·13	J. W. Ward (*B.C.W.*, Dec. 1895).
Accrington, . .	61·46	24·84	5·59	1·30	...	2·42	{with SiO_2}	0·32	...	3·84	...	Crace, Calvert, & Thomson.
American, . .	74·75	12·55	...	5·28	1·28	0·85	...	2·27	...	3·23	...	Langenbeck.
American (Bedford, Ohio), . .	57·28	21·13	8·52		5·79	2·13	...	...	...	5·22	...	D. H. Ries.

* This, perhaps, may be considered the most typical clay for the purpose.

Blue Ball-Clay.—The white-burning naturally plastic clays known to Staffordshire potters as blue ball-clays occur in Tertiary strata. The deposits have been variously classified by geologists as of Miocene and of Eocene age.

In Great Britain three distinct yet correlated districts form the com-

mercial sources of these clays, namely:—(1) Around Wareham, Norden, Goathorn, Creech Grange, and Corfe Castle, in the northern part of the Isle of Purbeck, Dorsetshire; (2) around Kingsteignton, Teigngrace, Homers, Decoy, and Newton Abbot, in South Devonshire; (3) around Marland and Merton, near Torrington, in North Devonshire; their respective shipping ports being Poole (Dorset), Teignmouth, Bideford, and Exmouth (Devon).

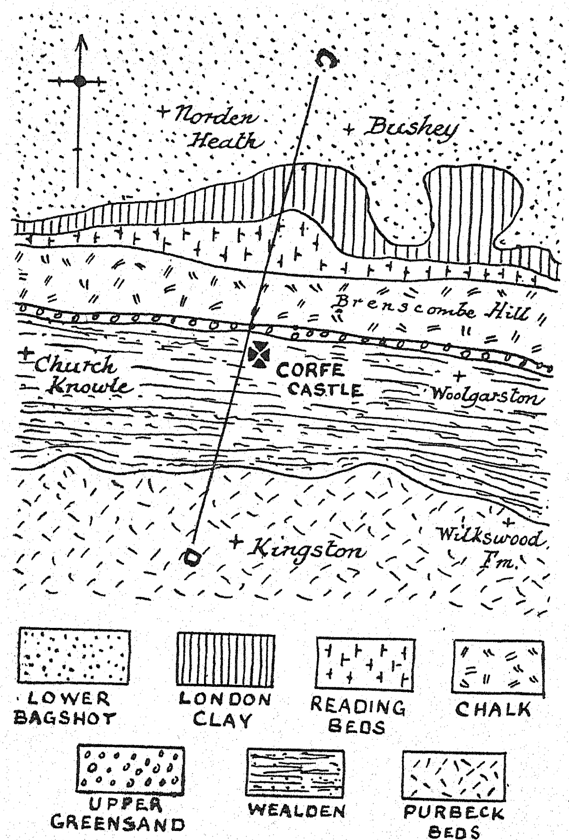


FIG. 146.—Sketch-map, Corfe Castle district. (*By permission of H. G. Montgomery, Esq.*)

In the year 1862 Messrs. Watts and Blake, of Newton Abbot, made a search for similar clay at Ballymacadam, near Clonmel (Ireland), and furnished a report of the search to the Clonmel Corporation. As only a small quantity of best quality of clay was struck by the borings, they relinquished the lease; but a local man, J. K. Fahie, affirmed that he had raised good clay from the ground, and also from another similar deposit at Cashel (Ireland).

Respecting the "Corfe Castle" (Dorsetshire) clay-field, Mr. G. F. Harris communicated some interesting particulars to the *British Clayworker* of September 1902. From this article we are kindly permitted to reprint some illustrations which help to explain the nature of the deposits.

Fig. 146 is a sketch-map of the district, indicating the disposition of the various strata.

Fig. 147 is a section across the district showing that the Lower Bagshot beds under Bushey and neighbourhood, as well as the other Tertiary beds resting on the chalk, are much inclined to the north, and that the whole of the beds, to the Purbeck inclusive, partake of this dip.

Fig. 148 is a vertical section of the beds as exposed at the Matcham clay-

works; here Mr. Harris explains that the beds dip nearly due south at an angle of 15 degrees, being exactly the reverse of what the average inclination of the Lower Bagshot beds is in this region.

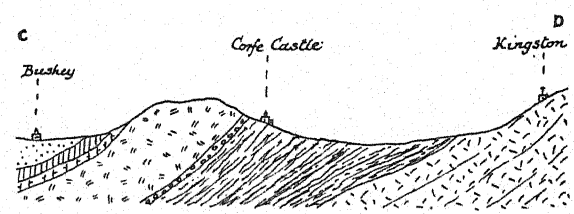


Fig. 147.—Section along line C D in fig. 146. (*By permission of H. G. Montgomery, Esq.*)

Particulars of the section at Matcham clayworks are as follows (fig. 148):—

Black earth and surface material with flints.

(*a*) Loose white sands with ironstone bands at base, 20–40 feet.
(*b*) Stiff yellowish or variegated clay—"pipeclay," 30 feet.
(*c*) Pure "potter's clay" with leaves, etc., 8 feet.
(*d*) Lignite with clay at base, several feet.

The loose sands are said to be very full of water and exceedingly troublesome. The yellow or variegated clay is taken off in large oblong spits and left in the workings. The pure "potter's clay" is the article so much sought after; it is a soft, white, and somewhat unctuous clay. (*British Clayworker*, September 1902, pp. 189, 190.)

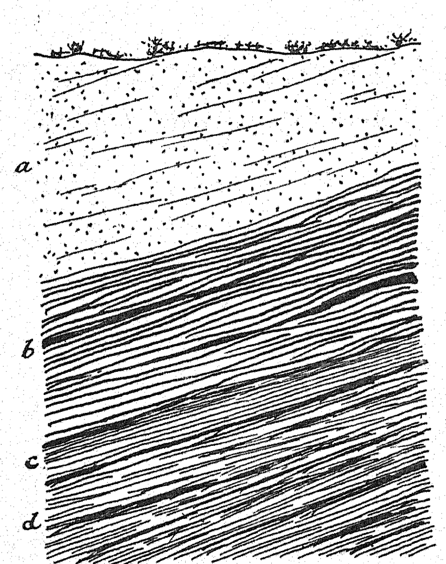


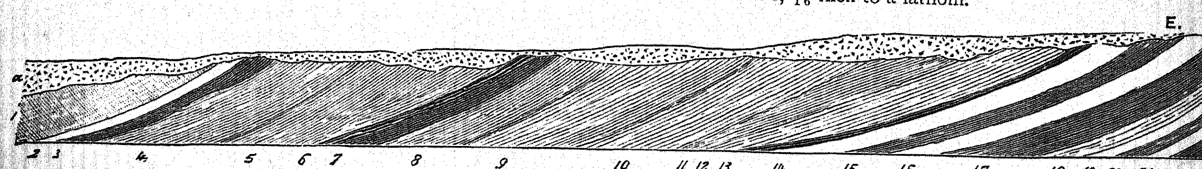
FIG. 148.—Section of Lower Bagshot beds at the Matcham clayworks. (*By permission of H. G. Montgomery, Esq.*)

Very extensive deposits of soft, unctuous plastic clays, associated more or less with sandy clays, loams, and gravel beds, are found also to the north of the River Frome in the Poole trough, and for many miles around Poole, Parkstone, and Bournemouth; but as comparatively few of these maintain a sufficiently white colour when burnt in a whiteware potter's kiln, they are not classed as blue ball-clays by Staffordshire potters, but come under the category of ivory ball-clays, siliceous buff clays, and drain-pipe clays. The two former will be referred to in another paragraph shortly.

In South Devon the principal mines for whiteware potter's clays are situated at Kingsteignton, Knighton, and Newton Abbot, all comprised in the Bovey Basin. In February 1862 J. H. Key, Esq., of Newton Abbot, communicated a highly instructive paper,

relating to these clay deposits, to the *Quarterly Journal of the Geological Society*, from which the following interesting excerpt is by permission drawn:—"The Bovey Basin is a depression beneath the level of the surrounding country; its length from Bovey Tracey to about two miles south of Kingskerswell is about ten miles; its breadth at the upper end about two and a half miles, becoming much narrower towards its southern extremity. Two rivers, the Teign and the Bovey, both having their sources in the granite of Dartmoor, run into this basin, meet above Storer, and fall into the sea at Teignmouth. The Teign, the larger and more circuitous, for about thirteen or fourteen miles before entering the Bovey Basin, flows through the slate; and the Bovey River, rising near the centre of the moor, crosses for a short distance the slate, and runs into the basin at its upper end. . . . . For more than a hundred years the Bovey Basin has been worked for pipe and potter's clay, sending off annually large quantities from its shipping port, Teignmouth. . . . . In the northern part of the basin, near Bovey Tracey, an extensive pottery has been established, excavating the greater part of its fuel for many years from the adjoining beds of brown-coal or lignite. . . . . Commencing on Knighton Heath, and running down the eastern side of the basin, are three principal parallel beds of clay (used in commerce), resting on, separated, and covered by other parallel beds of muddy clay, silt, sand, and gravel, all having a western inclination or dip. On the plan of the Bovey Basin presented to the Society (not published) the bed to the east, marked red, is the pipeclay (called locally the 'white body'); the two western beds, marked green, potter's clay (or the 'black body'); and the parallel beds of coarse clay, sand, etc., marked brown. . . . . South of the Newton Railway Station the beds of fine clay thin out to a mere trace, but occur again at the Decoy as a well-defined and regular deposit, but here the dip is changed from west to east, the pipeclay now being found to the west, and the potter's clay, accompanied by seams of lignite, to the east. Further south, the beds of fine clay thin out again, still keeping their eastern inclination; become again well defined at Aller, especially as regards the potter's clay and lignite (the pipeclay having here lost its distinctive qualities, being mixed up with sand and stained with ochreous matters). . . . .

FIG. 149.—Section of the clay-beds near New Cross. Scale, $\frac{1}{16}$-inch to a fathom.



a. 'Head' of gravel.

Potter's clay series.
1. Sand and gravel.
2. Clay.
3. Fine clay.
4. Silt.
5. Muddy clay.
6. Brown clay, with seams of lignite.
7. Fine brown clay.

8–12. Beds of coarse clay, sand, and gravel. (The space occupied by these beds is shortened.)

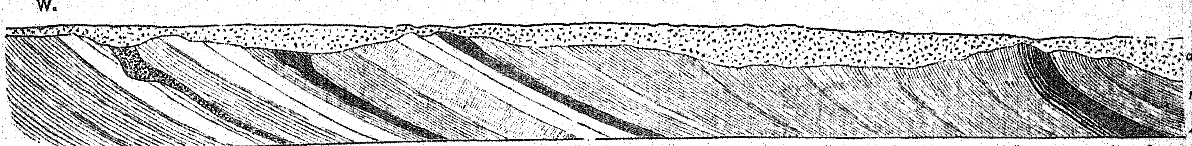
Pipeclay series.
13. Brown clay.
14. Stiff white clay.
15. Pipeclay.
16. Hard stiff clay.
17 and 18. Muddy clay.
19. Stiff white clay.
20 and 21. Pipeclay.
22. Muddy clay.

The beds dip to the west.

"Fig. 149 is a section across the beds of pipe and potter's clay, on the eastern side of the basin, near New Cross. It is constructed on data obtained from the inspection of deep and shallow pits from Knighton to Newton Marsh, from reports of the workmen, from borings, and from the superintendence of the Newton Marsh clayworks. This section will nearly represent the stratification of the continuous clay deposit from near Knighton on the north to the Newton Railway Station; with the difference that at the commencement of the deposit the seams of fine clay are thin, somewhat irregular, and to some degree mixed with quartz gravel. The dip is also greater than in the section; and in several places the clay-beds show the action apparently of running water, portions of the fine material having been evidently washed away, so that the fine clay runs down to a considerable depth almost perpendicularly. From Knighton southwards the beds of fine clay increase in thickness, purity, and regularity, to below New Cross, where they begin to diminish in thickness, until lost south of Newton Railway Station. In two or three places narrow bands of coarser clay, generally stained, run across the finer clay; and in several places the pipeclay forms two beds. . . .

FIG. 150.—Section of the clay-beds at the Decoy. Scale, $\frac{1}{18}$-inch to a fathom.

W. E.



a. 'Head' of gravel.

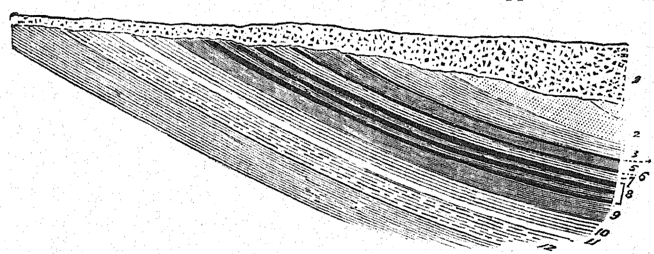
Potter's clay series.
1 and 2. Muddy clay.
3. Fine brown clay.
4. Small seams of lignite separated by thin beds of clay.

5–11. Beds of muddy clay and sand.

Pipeclay series.
12. Dark clay.
13. Stiff clay.
14. Pipeclay.
15. Sand, fine and coarse.
16. Muddy clay.
17. Fine dark sand, with leaves and seeds.
18. Brown clay.
19. Stiff white clay.
20. Pipeclay.
21. Rough muddy clay.
22. Fine dark sand, with leaves, seeds, etc.
23. Stiff clay.
24. Pipeclay.
25–28. Fine clay, with pink stains.

"Fig. 150 represents a section of the beds of clay, etc., at Decoy, and has been constructed from numerous observations made at the spot and in its vicinity during ten years. All the seams of clay shown in the section have been worked for considerable distances longitudinally, from 60 to 100 feet transversely, and to depths of from 30 to 90 feet. The inclination of the strata here is much greater generally than, and in the opposite direction to, that in the section, fig. 149 It will be observed, however, that the superposition of the beds is almost identical with that in the last-named section, taken in the upper part of the basin. . . . . Here and there a smooth water-worn stone, generally of quartz, but sometimes slate, is found embedded in the clay. Nodules of iron pyrites, of all sizes, from that of small shot to that of an egg, are in some places abundant. Detached pieces of lignite, too, are very common—sometimes with the surface changed into mundic. The clay and accompanying beds at Decoy rest against the Greensand Hills surrounding this portion of the basin; and the strike of the beds forms a segment of a circle, somewhat conformable in direction to the shape of the hills.

FIG. 151.—Section of clays and lignites at Aller. Scale, $\frac{1}{24}$-inch to a fathom.



1. 'Head' of gravel.
2. Sand.
3. Muddy clay.
4. Lignite.
5. Clay.
6. Lignite.
7. Clay.
8. Three seams of lignite, separated by fine clay.
9. Fine clay.
10. Rough clay.
11. Fine clay.
12. Rough clay, with gravel.
13. Rough sand and muddy clay.

The beds dip to the east.

"Fig. 151 shows a section (constructed from numerous observations whilst superintending the works during several years) of the potter's clay and lignite beds at Aller. Here the lignite, separated by beds of clay, is more developed than at the Decoy. No fine pipeclay has been found at Aller; but underlying the beds shown in the section, and occupying the position of the pipeclay, are rough clays, highly stained with ochre, all having an eastern dip. . . . .

"The clay-beds throughout the deposit show no signs of disturbance by

slips or faults; they seem perfectly unaffected by any other power than that of water. . . . ." (*Proceedings of the Geological Society*, Key, "Bovey Deposit," February 1862.)

Mr. J. H. Key then adds some interesting comments upon the nature of the gravel "head" which lays uncomformably upon the upturned edges of the clay-beds, and becomes deeper at the centre of the basin; concluding by observing that, amid proofs of teeming vegetation, it is strange not a fragment of bone or shell should indicate the existence of animal life around the old lake.

In North Devon, Marland Moor, Merton Moor, Greenings Moor, Clay Moor, and Bury Moor, on the banks of the River Muir, near Torrington, are the centres of the clay-workings. They are practically on the northern slopes of Dartmoor, and Mr. Key says that the "deposit resembles that of the Bovey Basin, both in regard to the quality of the clay and the manner in which it lies. . . . . The Merton clays are deposited in beds sloping at angles similar to those of Bovey. The deposit is entirely surrounded by hills, except at one point, where a chasm of but short width has been worn away, affording a passage to the drainage of the basin into the Torridge. It is plain that a fresh-water lake existed here, in which clays, brought by streams from the northern slopes of Dartmoor, became deposited; and that by the wearing down of the chasm the lake has drained itself, and the clays have become exposed in the same manner as are those of Bovey Basin." (*Proceedings of the Geological Society*, Key, "Bovey Deposit," February 1862.)

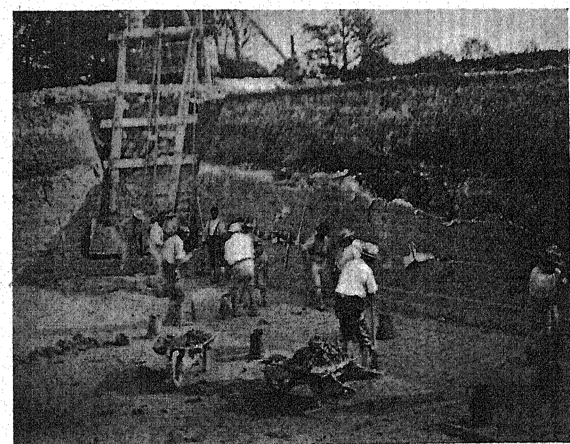


FIG. 152.—Marland clay-pit, N. Devon. (*By permission of E. Holwill, Esq.*)

Further interesting particulars relating to this deposit appeared in the *British Clayworker*, April 1898, from which we learn that it is practically the only clayfield of any extent in North Devon, except local brickmaking clays and the red clay of Framington. How far the deposit extends towards Dartmoor, which is eighteen or twenty miles distant, has not yet been definitely proved, the workings being chiefly at the northern extremity of the basin.

North Devon clay has been worked a very long time. The use of Devon-

shire ball-clay for pottery is said to have been discovered by Astbury (about 1715), and by its means he vastly improved upon the old compositions and prepared the way for Josiah Wedgwood.

Until Astbury's time Devonshire clay had been solely used for making pipes (presumably tobacco-pipes). (*Hist. of the Art of Pottery*, p. 41.)

Josiah Wedgwood is said to have used North Devon clay, which at that time was conveyed to Bideford on pack-horses, and thence shipped to Thames and Mersey ports and other centres. The pack-horse gave way to a system of carting to Torrington, whence it was sent by canal to Bideford, this canal in turn yielding to the steel rail which now connects the clayworks with Torrington Railway Station.

The mines are now principally worked by the North Devon Clay Co., Ltd., who raise blue ball-clays, ivory ball-clays, stoneware clays, and tobacco-pipe clays. The illustration shows an open-pit working which runs some 10 or 12 feet into the clay. It shows, too, how such clay is cut into cubical shape for certain uses, the longitudinal and cross-cutting giving the working a chess-board appearance. The method of hoisting the clay out of the pits into railway trucks alongside the working will also be noticed. Here the solid body of white clay has an overburden consisting of red clay about 6 or 8 feet deep, below which the white clay extends to so great a depth that in some places the bottom has not yet been reached. (*British Clayworker*, April 1898.)

FIG. 153.—Open-pit working, N. Devon. (*By permission of E. Holwill, Esq.*)

The method of getting ball-clay in Devonshire is very well described in the *British Clayworker* for October 1903 thus:—"The method of working is very much the same in each district. When the vein is near the surface, or is under other marketable veins, it is got by means of open workings. The heading or overburden having been removed, as well as any top or waste clay, a level face of clay is laid bare. This is cut or scored by means of spades into squares of about 8 inches, one set of men working across the pit ('long scoring') and another cutting at right angles ('thwarting'). The digger follows, and, by digging under at a depth of about 8 inches with a wide, heavy

two-bill, cuts out the clay in 8-inch balls or cubes. These balls are selected according to the quality of the veins, and raised to the surface by means of hand or steam power, and then carted or trammed to the storing depots. . . . . When the vein lies too deep for open working, or is under waste or unsaleable veins, it must be mined. . . . . A shaft is sunk into the vein . . . . and from the bottom of this shaft headings are driven into the clay—the miner using a short two-bill with a blade about 6 inches wide, and lubricating it by now and again dipping the blade in water. These headings are about 6 feet high and proportionately wide, and timbered as the excavation proceeds, the clay being wheeled to the bottom of the shaft and raised by cranes to the surface. When a heading has been driven the required distance, the timber is taken out and the ground allowed to drop, and the next heading driven. When the vein is of sufficient thickness, another heading or level may be driven into the clay which has come down on the removal of timber from the first levels. In this way the clay is removed for a certain distance around the shaft, which is then abandoned and another sunk. In North Devon the veins lie at a very considerable incline, and rather a different practice is followed.

"The vein is traced by boring to the shallowest point or 'outcrop.' A shaft, either vertical or inclined, as the case may be, is sunk to the bottom of the vein, and an inclined heading driven into the vein—the heading being about 6 feet square. When the shaft is sunk to the bottom of the vein, and the heading commenced, a raised platform is erected at the mouth of the shaft, and from this a tramway is fixed to the face of the heading; on this a bucket or trolley is worked to bring the clay to the surface, being wound up by a steel-wire rope, and running back empty by its own weight. The top heading is driven, and the tramway continued as it goes, following the run of the vein, sometimes very steep, sometimes almost level, as far as the vein continues workable—that is, of good quality and of sufficient thickness. This incline is very closely timbered with baulks of about 10 inches diameter. . . . . On reaching the end of the vein, generally 300 to 400 feet from the shaft, levels about 8 feet wide are driven out at right angles, two men working on each side, and wheeling the clay to the trolley at the foot of the incline. These levels are timbered with small props . . . . and when they have reached the distance at which in practice it is found safe to work them (generally about 40 feet), the timber is drawn and the roof falls. Another 8 feet of the incline is then taken, and levels driven parallel to and in the same way as the first, and so the process is continued, until the clay for the width of about 80 to 85 feet is cleared back to the foot of the shaft, which is then abandoned, and another made some 85 feet further on.

"As the trolley of clay comes to the surface platform it automatically tips its load, and is allowed to run back to be refilled. The bankman examines the clay, and wheels it out on to a prepared stacking ground, where it lies

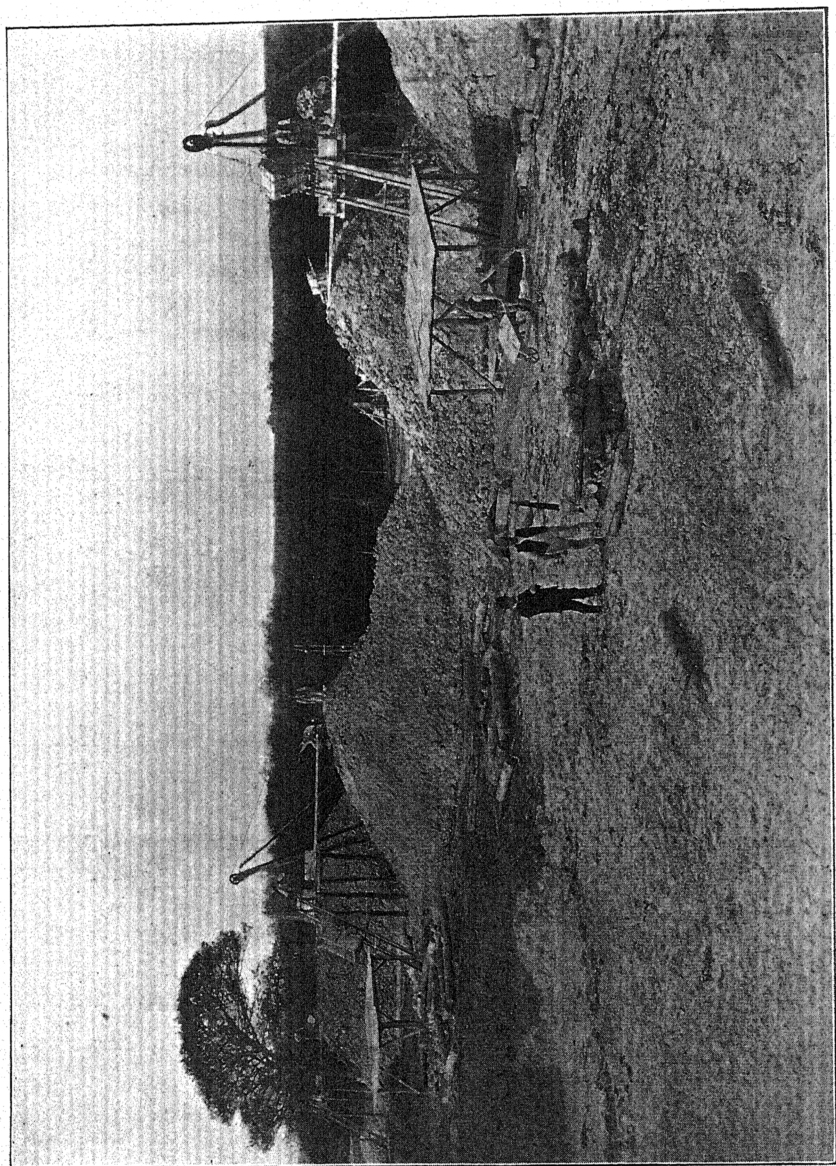


FIG. 154.—View of shafts working vein of blue ball-clay. (*B. Clayworker*, October 1903. *By permission of H. Greville Montgomery, Esq.*)

'to weather' until required for sale." (*British Clayworker*, October 1903, pp. 243, 244.)

From the foregoing it will be seen that a great variety of clays occurs in these districts, other than the blue ball-clays under consideration here. Some of these will be subsequently referred to under their respective terms, "black ball-clay," "ivory ball-clay," "siliceous buff clay"; others are only of use in other industries.

Respecting blue ball-clay—using the term in the sense it is understood by Staffordshire white earthenware potters—this is not now usually cut into cubes or balls from surface openings as formerly (and as done even now in the case of stoneware clays), but is mostly mined by underground workings from vertical shafts.

Blue ball-clays are the finest, most impalpable, most plastic, and purest clays of the series. When brought to the surface in native state they are of drab or bluish-drab colour, and after exposure do not "rust," or only very slightly, but become of more creamy-drab hue. When cut with a sharp knife, in a leather-hard condition, they expose a smooth, finely polished, even surface, which, on drying, is not easily marked by a black-lead pencil. The tint may at times be somewhat irregular or mottled. Lignite is rarely found in this clay, but pyrites in large and small nodules is very common, and, unless extracted by picking out or careful lawning, may give rise to objectionable speckiness.

Trial pieces of such clay, when burned under the conditions of a white-ware potter's biscuit oven, lose their plasticity finally, and assume an ashy-white colour, at the same time shrinking and becoming semi-vitreous, and having a conchoidal fracture.

With rare exceptions, no process of washing or preparation of any sort is pursued at the clay-mines; the clay is merely got in the native state, carefully selected seams only being taken, and the product laid out and exposed to weather until required for sale.

Blue ball-clay, as commercially bought and sold, contains from 18 to 25 per cent. of moisture, in addition to its water of combination; and as this is about 10 per cent., the total loss on calcination may be 28 to 35 per cent.

Freedom from colourant properties, extreme fineness of natural subdivision of the clay particles, great plasticity, and comparative absence of foreign detritus, moderate refractoriness and strength when burnt, constitute the most necessary and serviceable characteristics of what is called by whiteware potters "blue ball-clay."

The plasticity and moderate vitrescence enable them to bind into a body, before and after burning, other desirable ingredients, such as ground calcined flint and kaolin, and thus facilitate the manufacture.

In France clays known as "*terres réfractaires*," "*terre brune*," "*terre alumineuse*," and the like, having similar properties, are found mostly in the districts of Montereau, Montpothier, Sully (Oise), Forges-les-Eaux, Victor de Oules, Villenauve, Rimont, Marignac, etc.

In Belgium this class of clay is found around Andenne, and possibly also near Tournai.

In Germany there are extensive deposits of such clays. They are usually assigned to "Braunkohlen" formation, which is equivalent to our "Miocene." The deposits are met with mostly in the lower valleys of the *Rhine* and the *Elbe*, and on the Rhine Plateau near Grünstadt (Rheinpfalz).

Around Coblenz and Vallendar in the Rhine Provinces, and in the Westerwalder (Hessen Nassau), a considerable industry in these and kindred clays is carried on, one firm alone claiming to raise five hundred tons a day. And some of these clays so closely resemble those of Devon and Dorset, that individual samples, either raw or burned, would be quite indistinguishable unless marked. They possess the necessary plasticity and fineness and the usual variety of refractoriness. The clays are applied to the manufacture of white earthenware and tiles, as English clays are, and, in addition, are used by glassmakers. Large quantities also are exported to Holland, Belgium, and France. The principal deposits in the Elbe valley are understood to be those at Borna, Lothair, Bautzen, etc.

In several cases the same districts appear to yield clays much whiter in the native state than the Devon and Dorset ball-clays. These have the colour of deposited kaolins; some of them do not burn white, while others burn as white as china-clay.

Around Klingenberg and Mechenhard, in Bavaria, remarkably fat plastic clays are found, and are used in graphite crucible manufacture, and for stoneware and terracotta; but they are so very plastic they always need admixture of weaker clays.

In Canada, so far as the writer can ascertain, at present no such clay has been discovered and identified, except perhaps in almost inaccessible regions on the Missanabie River.

In the United States of America the states yielding ball-clay, or what passes for such, are Kentucky, Tennessee, Missouri, New Jersey, Florida, and South Carolina.

The returns issued by the U.S. Geological Survey Department for the year 1901 indicate that Kentucky yielded 8900 tons, and "other states" together 12,108 tons.

In the map published by Dr. Heinrich Ries, in his professional paper on *Clays of the U.S. East of the Mississippi River* (p. 284), ball-clay deposits are indicated by "X" in blue ink. By this means deposits are shown to exist at Mayfield (Ky.), Paris (Tenn.), Amboy (N.J.), and Edgar (Fla.). As to the

last-named locality, for reasons given elsewhere, the writer thinks this is an error.

Dr. Ries' map demonstrates forcibly the close relationship between Paris (Tenn.) and Mayfield (Ky.); they appear to be only some fifty miles apart, in a direct line, and are in the same river-basin—a tributary of the Ohio River, near its junction with the Mississippi. The clay deposits of these districts, in all probability, have a kindred origin somewhere on the western slopes of the Appalachian Range.

In Kentucky Dr. Ries has shown that a very great variety of clays occurs. The eastern portion of the state being, we understand, largely composed of carboniferous strata, numerous fireclays of the coal-measures are found there; of these many analyses are given on p. 122 of *Clays of U.S. East of the Mississippi*. The "ball-clays," however, are apparently only found in Western Kentucky, in a district known as the Jackson Purchase Region, laying between the Mississippi, Ohio, and Tennessee Rivers. It will strike a Devon or Dorset man as very significant, when he reads Dr. Ries' observations, and finds him frequently mentioning gravel, brown loam, silt, sand, lignite, greenish claystone, ochre, ochreous clays, and chalk bluffs, as being associated with or in proximity to the deposits of white pipeclay, and black and brown and drab and bluish clays, of Western Kentucky.

Dr. Ries, quoting from a report on the Jackson Purchase Region, gives the geologic section of the Tertiary strata thus:—

> "Lagrange: stiff plastic clays, variegated in color and interstratified with whitish sand, and carrying leaf-impressions.
>
> "Lignitic: black arenaceous clay and claystone.
>
> "Porter's Creek: massive and jointed clay, locally called soapstone.
>
> "Hickman: siliceous claystone over a thick bed of buff-colored clays."

Dr. Ries continues:—"Most of the clays in this part of the state, which we found in all the counties, appear highly refractory before the blowpipe. The classes recognized are:—

"1. Drab clays of Hickman bluffs.

"2. Siliceous clays from Columbus bluffs, which face the Mississippi River at Columbus, and at the chalk banks below. These rise more than 100 feet above the town. The upper portion is made of 30 feet each of gray silt or loess and gravel. Under the gravel is variegated-colored plastic clay, 15 feet thick; under this, 85 feet siliceous clays. These clays burn hard to a light-creamy color. They are finely siliceous. . . . . These were supposed to belong to the lignitic (Tertiary) group, and are found farther east associated with the belt of dark clay in M'Cracken and Graves Counties.

"3. White or light-colored plastic clays. These form beds of greater or less size in each of the counties, and are put in what is known as the Lagrange group of the Tertiary. The clay has been deposited since the deposition of

the black clays. It usually is white or light purple in color, fine grained, and varies in thickness from a few inches to many feet.

"4. Black and bluish-black clays. These are confined to the cretaceous and the lignitic or lower Tertiary belt that passes through Calloway, Marshall, M'Cracken, and Ballard Counties, and to the Port Hudson group of the Pleistocene, which occurs in the valley and bottom land of the three bordering rivers. The dark color is due to vegetable matter. These clays are said to be refractory." (*Clays of U.S. East of the Mississippi River*, p. 125.)

Dr. Ries then gives chemical analyses of a large number of these clays. (See pp. 126, 127, *ibid.*)

Proceeding, he observes:—"Clays which are easily fusible are found in a number of the counties, but are said to be confined chiefly to those on the eastern side of the Jackson Purchase Region, namely, in M'Cracken, Graves, Marshall, and Calloway Counties. They vary in color from nearly white to black. Some are highly gypseous, while others are sprinkled with vivianite. They are pre-Pleistocene, and are overlain by gravel, sand, and brown loam of that period. They include some of the white varieties belonging to the period intermediate between the Tertiary and Pleistocene and the black clays of the next higher or Port Hudson group."

On account of the commercial importance of the clays found in Western Kentucky, Dr. Ries devotes some space to more detailed description of the deposits of the several counties separately. Referring to Calloway County, he writes:—"A great variety of clays occurs within the county. These are both refractory and non-refractory, and many are well situated for workings. The black joint clays occupy a belt from the Tennessee line northward through Murray and Wadesboro into Marshall County, being exposed at a number of points along the west side of Clark's River. They are exposed in the southern part of the county west of New Providence. A prominent exposure is at the Paris bridge one mile south of Murray. Other exposures are seen in the bluffs of creeks north of Murray, and in the ravines that border the road north to Wadesboro. They are from 10 to 20 feet thick.

"White pipeclays are abundant, and found chiefly on the east and west of the black joint clay-belt. A highly plastic white variety is found near Mayfield. . . . The same clay appears in the branch south of this place, and also in the bluffs east of the river, at Backusburg, to the east of Murray. On a line passing through it north and south are several beds of white clays, notably at Russell's Pottery. They burn to a good color, but difficulty was experienced with the crazing. Another locality of white clay is in the river east of New Providence." (*Clays of the U.S. East of the Mississippi River*, p. 131.)

One of the firms raising ball-clay at Mayfield (Ky.), the writer understands,

is The Kentucky Improvement and Construction Company, and their product is known in the States as "Mayfield" ball-clay. Another quality is known as the "Excelsior" ball-clay; this, it seems, is raised in the vicinity of Covington (Ky.), and is an approved quality. Professor Binns selected it as a typical clay for use in a series of investigations which are described in *Trans. Am. Cer. Soc.*, vol. v. p. 281.

He gives its rational analysis thus:—

Clay substance,	63·26
Quartz,	35·00
Felspathic matter,	1·74

This analysis, however, would seem to indicate a clay of too siliceous character to be properly classed as whiteware potter's ball-clay, although it might be a stoneware potter's clay.

In the State of Tennessee ball-clay is mined near Whitlock, and also near Paris, both in Henry County (Tenn.). These mines have been operated by Mr. Mandle since 1898, and yield about fifteen thousand tons a year. The clays are marketed in native state without washing.

The Whitlock ball-clay, also known as Tennessee ball-clay No. 1, is said to mix well with water, and quickly screen, and when washed through a 120-mesh sieve it leaves hardly any residue.

The rational analysis of this clay is as under:—

Clay substance,	86·20
Feldspar,	2·70
Flint,	11·10

which apparently is somewhat siliceous; however, its plasticity is claimed to be equal to that of English ball-clay, tests indicating no difference between this ball-clay and the English. Tests were carried as high as 60 per cent. non-plastic material to the mixture. When moulded and dry this ball-clay is said to be capable of bearing a great deal of handling, and in strength to be on an equal with English ball-clay. The total fire-shrinkage is 15 per cent. at the m.p. of Cone 8, which is the average temperature of potter's biscuit kilns. At this heat it burns to a dense body with a creamy-white colour. Its behaviour under glaze evinced no material difference when tested under similar conditions against English ball-clay.

A small sample of this ball-clay kindly sent over to England by Mr. I. Mandle, the proprietor of the mine, was inspected by the writer. The colour of the clay in its native state was found to vary between creamy-white and light-drab, and had the general appearance, texture, fineness, and density of superior Devonshire whiteware potter's ball-clay, very like the quality known in Staffordshire as "china-ball."

The light-drab-coloured specimen, when burned in a Staffordshire potter's

kiln, was particularly white and free from specks or stains for a ball-clay; exhibiting in this respect the characteristics of best white Devonshire ball-clay.

The creamy-white clay burned to a very good white, but just a little more creamy shade than the drab. This also is a characteristic often observed in English ball-clays.

The Paris (Tenn.) ball-clay, or Tennessee ball-clay No. 3, has a brown colour in its dry state, mixes well with water, and may then be screened through a 120-mesh sieve without any residue. By screening through a 175-mesh sieve, which would be equal to washing clays on a commercial scale, it leaves 10 per cent. residue, which consists mainly of fine-grained sand.

The rational analysis of the clay is as follows:—

Clay substance, ...	91·53
Feldspar, ...	2·70
Flint, ...	5·95

When mixed with water to a plastic body it has a fatty feeling, and will shine when polished with a knife. It will carry as high as 72 per cent. of non-plastic material such as flint, feldspar, or whitening.

The shrinkage of the clay is at Cone 1 heat 12·5 per cent., and at Cone 8 heat 18 per cent. The clay burns white at a Cone 010 heat; at Cone 1 its colour is still white, the body is much closer; at Cone 8 heat it is a vitrified grey body.

Tested against English ball-clay it is claimed to be of equal plasticity, but of better colour, and that 4 per cent. more Tennessee ball-clay could be used in standard American semi-porcelain and whiteware bodies without injury as to their colour. This clay is classed as a very good plastic clay suitable for all purposes where the use of a ball-clay is necessary in order to obtain pottery bodies which will be fit to be jiggered and pressed.

A sample examined cursorily by the writer exhibited in its native condition a brownish-drab colour, very brown indeed when moist; possessed a fine mellow texture; yielded a polished surface when cut with a sharp knife; was unctuous to feel; and generally "right" as a good ball-clay of the Devonshire type.

When burned in a Staffordshire potter's kiln the sample was a pretty creamy-white, not quite as vitreous as desirable, but good; far better, indeed, than plenty of South of England clays, and remarkably free from specks or stains. There was, however, some disposition to split in the particular piece tested. Whether this defect would be found in all parts is uncertain, but it is perhaps not difficult to control in actually using such clays.

Dr. Ries mentions these deposits of ball-clay in the State of Tennessee. Along with several others, he writes, under the classification *Tertiary*, as

follows:—"In Western Tennessee the plastic clay immediately underlying the Lafayette formation serves as the basis of a rather active stoneware and firebrick industry. The section usually seen in the clay-pits involves red Lafayette sands, which seem to overlie unconformably the beds of stoneware clay and white sands. . . . . In the pits of the Irwin Clay and Sand Co., one and a quarter miles east of the station (Grand Junction) . . . . the section given by E. C. Eckel is:—

Red sand,	......
White sand,	8 feet.
White clay,	8 feet.
Gray lignitic clay,	8 feet 10 inches.
White clay,	20 feet.
White sand,	......

"The clay deposits are very irregular, sometimes running together to form overlapping lenses in the white and yellow sand. . . . . The clay at Hico, three miles south of Mackenzie, is shipped to the potteries at Akron and East Liverpool, Ohio, and Louisville, Ky. The clays from Hollow Rock are shipped to Nashville. . . . .

"Three miles east of Currier are the pits of I. Mandle, where an area of 60 by 50 feet has been opened up. The section is as follows:—

East Side.	West Side.
2 feet clay.	Reddish sand.
4 feet clay.	15 feet light gray clay.
1 foot black clay (lignitic).	1 foot black clay.
5 feet brown clay (ball clay).	5 feet ball clay.

. . . . The light-gray clay is shipped to East Liverpool, Ohio, for saggars. The ball-clay is known as Tennessee ball-clay No. 3." (*Clays of U.S. East of Mississippi River*, p. 245.)

Then follow remarks upon results of chemical analyses of both of the principal ball-clays already referred to, such as have already been given above.

Dr. Ries explains that the Tennessee No. 3 ball-clay is located five miles from Paris (Tenn.), and is shipped from Currier, which is three miles from the mine.

In the State of Missouri ball-clay is mined at Regnia, Jefferson County, about forty miles south-west of St. Louis (Mo.). These mines have been operated since 1878 by Mr. I. Mandle, and the output is said to be some five thousand tons per annum. Missouri ball-clay is marketed in its crude native state, and does not require washing. When dry, it is of light-grey colour, and has a smooth fatty feeling. It mixes well with water and is remarkably free from grit. On account of its great binding power, it does not screen very readily through a 120-mesh sieve, but leaves a small residue, which consists of very plastic clay, free from sand.

The rational analysis of this clay is :—

Clay substance,	95·38
Feldspar,	3·42
Flint (? silica),	1·20

Missouri ball-clay will carry 73 per cent. non-plastic material, and is said to possess greater binding power than English ball-clay. The total fire-shrinkage at Cone 8 heat is 18 per cent., and the clay at that temperature burns to a grey-white, dense vitrified body. It was substituted on white-ware bodies for English ball-clay with satisfactory results in regard to colour of the finished product. It is also recommended for encaustic tiles, sanitary ware, etc.

Mentioning this clay, by the way, Dr. Ries, among other things, notes that its average tensile strength per square inch is 99 lbs.; the point of incipient fusion, 1800° F.; and the total fluxes, 5·15 per cent.

A sample, kindly sent by Mr. Mandle, of St. Louis, was examined by the writer. In its native condition it has a greyish-white colour, smooth and somewhat talcose appearance, saponaceous feel, is extraordinarily tough, yields a polished surface when cut with a sharp knife, and is in its raw state very much whiter than any British ball-clay with which the writer is acquainted. When burned in a Staffordshire potter's kiln it assumes a greyish or creamy-white colour, free from specks or stains, dense and highly vitreous; very similar to the very best Dorsetshire whiteware potter's blue ball-clay.

Undoubtedly this Missouri ball-clay, when used with suitable proportions of Tennessee ball-clays, and compounded into a whiteware body with flint, china-stone, and china-clay, should be capable of producing any of the ordinary white earthenware bodies.

In New Jersey State a large variety of more or less plastic clays are found, and these have been exhaustively described by Dr. G. H. Cook, formerly State Geologist, in a voluminous report issued in 1878, which, although confined chiefly to notes on fireclays, potter's clays, and paper-clays, disregarding the large number of clays used for making common bricks and red earthenware, extends over three hundred and fifty pages.

From Dr. Cook's report it seems that the only locality in New Jersey where clays at all comparable with English ball-clays are raised is near Woodbridge and South Amboy, at the mouth of the Raritan River. The district comprises about sixty-eight acres, and is intersected by very numerous navigable natural waterways; so much that all the mines are within a few miles of shipping facilities.

Judging by geological sections given by Dr. Cook, this Raritan plastic-clay formation is assigned to cretaceous age. This is confirmed by Mr. J. C. Smock, Acting State Geologist at the present time; and is supported by the researches of Dr. Morton and Mr. Conrad in 1834, and Sir C. Lyell in 1841.

The latter found fossils on the whole agreeing most nearly with European upper cretaceous fossils; but it should be noted that Sir Charles Lyell significantly remarks upon this series of sandy and argillaceous beds as "*wholly unlike our upper cretaceous system.*"

Dr. Ries, too, retains this classification apparently in his new publication, except that he calls it lower cretaceous, as Cook did.

But as Devon and Dorset clay-beds, and also Kentucky and Tennessee

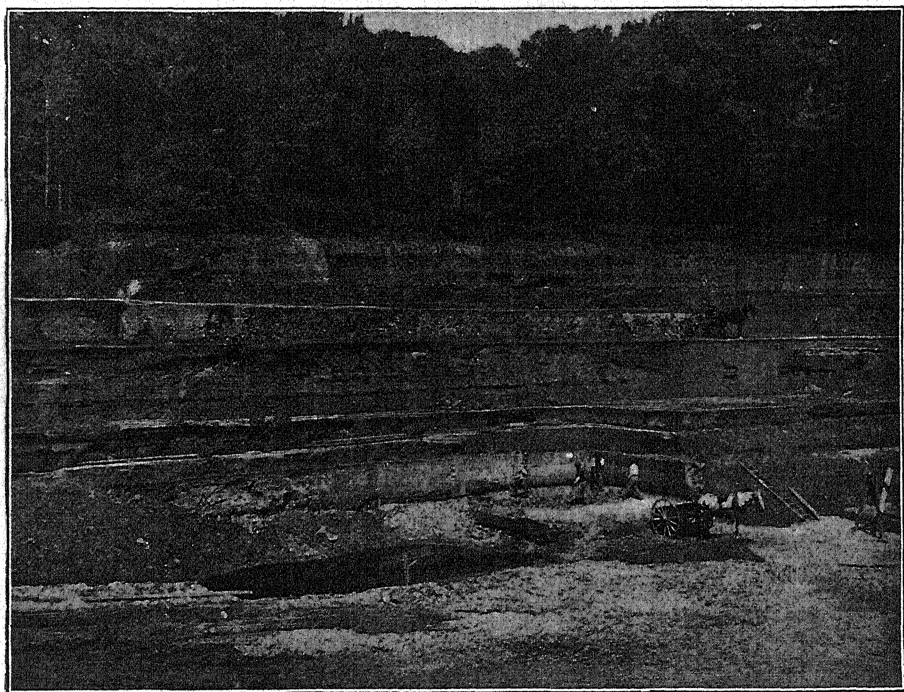


FIG. 155.—Clay-pit at Woodbridge, N.J., U.S.A. (*By permission of the United States Geological Survey.*)

clay-beds, containing lignite interstratified with sands and silts and plastic clays, are assigned to Miocene or Eocene groups of Tertiary strata, the lay observer, who cannot very well fail to remark the fact that these same phenomena appear to exist at the mouth of the Raritan River in New Jersey, may with some reason ask if it is not possible that the Woodbridge and South Amboy clays should also be grouped along with the Tertiary.

Sir Charles Lyell said: — "From New Jersey the cretaceous rocks extend southwards to North Carolina and Georgia, cropping out at intervals from beneath the tertiary strata, between the Appalachian Mountains and

the Atlantic. They then sweep round the southern extremity of that chain, in Alabama and Mississippi, and stretch northwards again to Tennessee and Kentucky. They have also been traced far up the valley of the Missouri." (*Elements of Geology*, p. 337.) This seems to establish the possibility of relationship between New Jersey and Tennessee and Kentucky clay deposits.

Of the very numerous seams of clays mined in the locality of Woodbridge, the one known as the "ware" clay or "whiteware" clay most nearly approaches English ball-clays; nevertheless it is different, being more friable, less plastic, crumbles easily on exposure, has a conchoidal fracture when dry, and is decidedly less vitrescent when burnt. Langenbeck refers to its binding power as being very low, and observes that for this reason, and on account of its deficiency of alkalies, not inconsiderable quantities of English plastic clay are imported. It is, however, of very fine quality, and burns remarkably white, presenting qualities approaching those of china-clay or kaolin.

In the State of Florida several clays have been found and raised for whiteware potters' use, some of which have sometimes been designated "plastic kaolin," and sometimes Florida ball-clay.

Upon inquiry for specimens of the raw clay in its natural condition, it transpired that this contained about 65 to 75 per cent. of coarse quartz sand, and necessitated a process of washing and sedimentation to separate the fine clay from the sand before the clay could be used by whiteware potters, very much in the manner china-clays are prepared. For this reason and others, the consideration of these clays has been relegated to the paragraph on china-clays.

Long personal experience of Devon and Dorset ball-clays renders this course unavoidable and indisputable, notwithstanding the concensus of expert American opinion, as expressed by Langenbeck, Ries, Binns, and others, in favour of the classification of Florida clays as ball-clays.

Only in very exceptional instances are blue ball-clays washed in England, and then for a reason totally different from that necessitating such treatment of Florida clay.

Chemical analysis also indicates that this clay is of the nature of china-clay, and Langenbeck has himself remarked upon the fact that "a much larger proportion of the American ball-clays approach the composition of kaolinite than do those of Europe." (*Chemistry of Pottery*, p. 100.)

Granted that it is not as easy to clearly differentiate between ball-clay and china-clay as may appear upon superficial consideration, yet it does seem reasonable to imagine that, while a deposited kaolin may be detritus from feldspathic rocks which had previously become kaolinized *in situ* before denudation, a blue ball-clay (in the sense understood in Staffordshire) may

with equal propriety be assumed to be a result of slow denudation of feldspathic rocks in their pristine chemical state, the kaolinization, which is often only partial, being frictional rather than chemical. (*Trans. Am. Cer. Soc.*, vol. v. p. 292 and p. 379.)

In South Carolina something approximating ball-clay seems to have been found, for in the *Pottery Gazette* of November 1903, Mr. Gotham, of East Liverpool, is reported to have said that "one-third of the ball-clay used in the state [presumably in Ohio State] to-day comes from South Carolina."

Mr. Mandle further informs me that Mr. Sant, an experienced clay merchant of East Liverpool, has examined many samples of so-called china-clay from South Carolina, all of which he found to be very plastic and free from grit, but none of which were good in colour when fired to Cone 8. These clays are said to be used mostly for wall-paper and linoleum. Mr. Sant is said to hold the opinion that these clays might more properly be classed as ball-clays than those of Florida.

If we now recall the observations of Sir Charles Lyell upon the general trend of the strata around the Appalachian Range, it will be evident that South Carolina is not at all an unlikely district in which to find ball-clays.

In New South Wales, Australia: the annual report of the Department of Mines and Agriculture of New South Wales for 1891 has an appendix in the form of a series of sections of strata passed through in the course of boring artesian wells. These reveal some intensely interesting facts; among others, that at the one hundred and twenty-first milepost on the road from Milparinka to Wanaaring, about 80 feet from surface, a bed of pipeclay exists 9 feet thick; and at the one hundred and sixth milepost, *i.e.*, in County Ularara, a bed of pipeclay 25 feet thick, with another of blue clay 109 feet thick some distance below. Then at twenty-sixth milepost on Louth-Wanaaring Road, a bed of white pipeclay 47 feet thick. White pipeclay is also found in County Landsborough, and at Yancannia in County Yantara. At Salisbury Downs, Co. Yantara, the clays of various kinds, including a bed of 513 feet of soft blue clay, total 909 feet thick. And at Belalie, Co. Irrara, the clays of various sorts are over 700 feet thick. Presumably, therefore, potting-clays are accessible in New South Wales.

Commenting upon the origin of white-burning natural clays, Professor Edward Orton, jun., of Columbus, Ohio, aptly observes that "Without going fully into the conditions which have brought these things about, we may say that the white-burning clays represent those rare conditions where a rock low in iron has weathered and broken down into a clay, without the intrusion of iron-bearing water or sediments from neighbouring rocks. Such a combination of events does sometimes happen, and hence we sometimes find clays which burn white. But since they can only grow by the weathering of igneous

rocks, they come almost wholly from the mountain districts, where granites and similar feldspathic rocks occur. Since transportation of clays in streams is almost certain to result in the blending of iron-bearing sediments with them, it follows that white-burning clays in the vast number of cases are primary, viz., found on the site where they have first been formed by weathering. But in some few instances, as in the Florida kaolins, white clays have actually been transported over long distances and redeposited as secondary beds, without collecting enough iron to throw them out of the white-burning class. The rarity of the conditions producing white-burning clays naturally makes them a very small item compared with the vast bulk of other clays." (*Trans. Am. C.S.*, vol. v. p. 379.)

Black Ball-Clay.—This term is applied to certain white-burning, fine impalpable plastic clays of Tertiary strata, very closely allied to whiteware potter's blue-ball clays, but deeply stained with dark-brown carbonaceous stain from lignite or brown-coal beds, and often also impregnated with pieces of lignite itself.

Seams of lignite, as the foregoing sections have shown, very often occur interbedded in the series of clay-seams, and interchange of natural water causes the stain to pass from the one to the other. The stain is of vegetal or organic nature, and is consumed on ignition; thus some of these naturally very dark-brown clays, particularly dark when damp, assume an intense whiteness after calcination in a whiteware biscuit oven, sometimes whiter than blue ball-clay.

The whitest-burning black ball-clays are found in South Devon, those of Dorsetshire usually burning rather less white; but even there, there are different qualities, some burning very much whiter than others. They are usually rather less plastic, and perhaps more sticky than blue ball-clays. They are generally mined from underground workings, as this enables the best parts only to be got out, and saves the expense of handling a great bulk of promiscuous and often unsaleable loam, silt, brown-coal, and inferior clay.

Black ball-clays are found also at Neuvic-sur-l'Isle (France), Andenne (Belgium), and near Vallendar and several other localities in Germany.

Langenbeck mentions similar clays in America, and tells us that he has often chemically examined such clays yielding as much as 4 per cent. of organic impurity of a flocculent nature—his method being to dissolve the clay in hydrofluoric and hydrochloric acids on a water-bath, and filter off the organic flocks on a tared paper, where, after drying, it is weighed.

As to the presence of iron in white-burning clays, Professor E. Orton observes:—"White-burning clays carry from a few hundredths of a per cent. of iron to considerably over one per cent. The more ferruginous contain much more iron than the purer grades of the buff-burning clays, whence it

is evident that quantity alone is not a sufficient explanation of the colour." (*Trans. A.C.S.*, vol. v. p. 380.)

TABLE OF ANALYSES OF WHITEWARE BLUE AND BLACK BALL-CLAYS, ETC.

Material or Source.	SiO_2.	Al_2O_3.	FeO, Fe_2O_3.	TiO.	CaO.	MgO.	Ca. Phos.	Alk.	Organic and Loss.	Combined Water.	Moisture.	Analyst or Authority.
Ball-clay (Dorset), . .	48·99	32·11	2·34	...	0·43	0·22	...	3·31	...	9·63	2·33	Weston.
Black clay (Dorset), . .	52·89	31·89	0·87	0·46	...	0·48	...	2·50	...	11·10	...	Bowes & Sims, 1904.
Best blue clay, . . .	46·38	38·04	1·04	...	1·20	trace	...	...	...	13·57		Ansted.
South Devon ball-clay, .	45·50	35·30	1·90	...	0·50	...	...	5·60	11·8	..	...	*Pottery Gazette*, February 1904.
,, ,, .	48·20	33·20	1·90	...	0·80	...	...	5·60	10·0	...	...	
North Devon clay, . .	49·50	33·60	0·80	...	0·10	0·58	...	1·18	14·24		...	*B.C.W.*, Oct 1903.
Longueville (brun) clay, .	46·89	27·00	1·10	...	2·60	...	...	...		22·38		Cocardon.
Montereau clay, . .	65·90	31·30	1·05	...	...	...	...	...	...	...	...	
Mechenhard (Bav.), . .	49·80	33·68	1·90	...	0·48	0·44	...	1·81	11·63		...	
Vallendar (dark - brown), calcined, ...	60·68	36·84	...	...	...	...	...	...	...	...	...	Vallendar Co.
Feuerstein clay, calcined, .	57·06	39·54	1·22	...	...		...	...	...	...	...	Vallendar Co.
Calloway Co. (Ky.), . .	59·83	27·80	0·83	...	0·15	0·24	...	0·82	...	10·42	...	Langenbeck.
Excelsior, Covington (Ky.),	55·58	32·29	0·31	...	...	...	...	2·24	.	10·07	...	Prof. C. F. Binns, M.Sc.
Mayfield (Ky.), . . .	56·40	30·00	...	...	0·40	trace	...	5·27	...	7·93	..	Dr. H. Ries.
"Ware"-clay, Woodbridge,	44·94	38·81	1·14	1·30	traces	0·11	...	0·17	...	12·97	1·23	Dr. Cook.
New Jersey clay, . .	46·18	39·08	1·11	..	0·42	0·35	...	0·51	...	13·04	...	Langenbeck.
Jefferson Co. (Mo.), . .	48·51	35·18	0·92	...	1·01	1·47	...	2·30	...	10·72	...	Langenbeck.
Florida plastic kaolin, .	45·39	39·19	0·45	...	0·51	0·29	...	0·83	...	14·01	...	Langenbeck.

Ivory Ball-Clay.—In Dorsetshire, on the north of Poole Trough, around Beacon Hill, Hamworthy, Longfleet, Newtown, Kinson Park, Branksome, Parkstone, and formerly on Branksea Island, and in North Devon at Marland clay-pits, near Torrington, are found, along with many other clays, certain special seams of plastic and almost impalpable clay, usually of creamy, drab, or blue-grey colour, very similar in many respects to blue ball-clay, except that, owing to the presence of intimately diffused salts of iron, they are evenly discoloured throughout, and burn to a yellowish-buff colour. Hence they are quite unsuitable for the manufacture of best whiteware. These clays, however, are thereby rendered peculiarly suitable for the preparation of bodies which are required to burn a creamy-ivory tint; and this is often a desirable tint for tiles.

When made into "slips" with water, or often when newly cut, these ivory ball-clays evolve a characteristic sulphurous odour. It is highly probable, therefore, that the diffused salt of iron is either a sulphide or sulphate. And, indeed, pyrites is frequently met with in such clays, and sometimes exists in

such a granular or nodular condition as to render the clay unserviceable, because of the speckiness of ware so produced.

In selecting the seams, the degree of fineness and plasticity, absence of concretionary pyrites, of gravel, and sand, must influence the choice, in addition to the tones of colour when burnt, which vary considerably in different seams, and must be carefully tested from time to time in all cases where uniformity of tint is a *sine quâ non*.

A characteristic of these ivory ball-clays, differentiating them from the blue ball-clays, is that they almost always "rust" or "purge" on exposure, a thin yellowish ferruginous film quickly forming on exposed faces, similar to that often seen on stoneware clays.

An analysis of a typical clay of this class, especially determined for publication in this treatise, by Messrs. Bowes & Sims, analytical chemists, Radford Street, Blackley, Manchester, yielded the following results:—

Silica,	55·05
Alumina,	33·09
Ferric oxide,	0·44
Ferrous oxide,	0·39
Lime,	0·16
Magnesia,	0·79
Alkalies,	0·99
Combined water,	8·21
Titanium dioxide,	1·55

In France similar clays are found near Montpothier, Longueville, Montereau, Sully par Songons, etc.

In Belgium, at Andenne, what is called "blanche" clay answers to the above description.

In Germany the "weiss" clay of Vallendar and the Westerwald, and some of the Hettenleidelheim clays, appear to be equivalent to ivory ball-clay.

In the United States undoubtedly similar clay will be found associated with the indigenous ball-clays of Tertiary strata. Clay found at Redwing, Minnesota, although physically different, possesses remarkably similar characteristics when burned.

Siliceous Buff Clays.—The two chief sources of these in England are the Tertiary deposits of Devon and Dorset, and the clay-pockets of mountain-limestone hills in Derbyshire, East Staffordshire, and North Wales.

Weathering may generally be dispensed with, but great care must be exercised in selection, especial attention being devoted to the degree of siliceousness, of fineness, of solidity and regularity, and of freedom from *iron pin*, *mundic*, and all pyritous concretions, also from tendency to cut. Siliceous clays of moderately fine grain, but not too fine, and holding together with moderate firmness when damp, will be found most serviceable; the

Dorset claymen call them "mild" clays, *i.e.*, not tough. When quite dry such clays may be written upon easily with ordinary lead-pencil, and this is a characteristic very clearly distinguishing them from ivory ball-clays, which often occur in the same pits. Such clays are largely used for deep cream-coloured and light-buff glazing tiles, and yield warm, agreeable, cheerful tones of colour in the finished wares.

The shrinkage of such clays during burning is considerably less than that of blue ball-clays and ivory ball-clays, and sometimes less than *body*-clay. This feature must be kept in mind when compounding *bodies*, and must be specially tested for in each supply from time to time.

The chemical analysis of a typical clay of this sort is as under:—

Silica,	77·70
Alumina,	15·59
Oxide of iron,	0·48
Lime,	0·56
Magnesia,	0·28
Alkalies,	1·14
Water and loss,	4·25
	100·00

This seems a very small percentage of iron oxide for the colour-effect, but possibly it acts as a coating on the silica grains, as in red clays.

Siliceous, more or less plastic buff-burning clays occur in France at Poitiers, Montereau, Boulogne, etc.; in Belgium at Andenne, and, the writer believes, also at Tournai.

In Germany clays of this class, almost indistinguishable from those of Devonshire and Dorsetshire, occur in the Rhine Provinces and the Westerwald; while at Veltin, near Berlin, a plastic calcareous clay is found, which burns to a cane colour and is used for making buff tiles.

In the United States finely siliceous buff-burning clays, possessing the requisite qualities, apparently exist at Redwing, Minnesota; also in Western Tennessee, Western Kentucky, Alabama, Maryland, and New Jersey. Indeed, South Amboy, N.J., has been one of the principal sources of this class of clay on the U.S. Atlantic coast for many years; so long ago as 1874 about twenty thousand tons a year of stoneware-making clays were raised in New Jersey, and this is very similar. In New Jersey the clay is sometimes raised by mining, and sometimes by open workings, all of which is minutely described in Dr Cook's 1878 report on New Jersey clays.

Respecting siliceous clays of mountain-limestone pockets, these usually are somewhat irregular deposits, and the clays are often of coarser grain than the Tertiary clays of Devon and Dorset. George Maw, Esq., F.G.S., has written a very instructive monograph on the nature and origin of such deposits. (See *Geological Magazine*, June 1867.)

Brongniart's comments upon the clays of Abondant, near Dreux, France, lead to the inference that they may be mountain-limestone pockets, such as occur in England in E. Staffordshire, Derbyshire, and N. Wales.

China-Clay or Kaolin.—Native or "virgin" china-clay—sometimes called carclazyte, after the name of one of the oldest mines near St. Austell, the Carclaze mine—is generally supposed to be a form of decomposed or metamorphosed pegmatite, haplite, granite, or giant-granite; but this apparently plausible theory of its occurrence is, by some writers, considered merely provisional. Its natural appearance is that of a crumbling yellowish-white mass, containing many translucent crystals of quartz, associated with a yellowish-white or greenish-white flour-like substance (kaolinite), together with particles or laminæ of mica promiscuously and sparsely distributed throughout the mass. The colour, coarseness, and other physical qualities vary with the locality, and sometimes even in the same quarry or sett.

In England china-clay rock is found on the sides and in depressions of Plutonic hills, and is said to be sometimes as much as sixty fathoms deep. From these formations it is raised in considerable quantities in the counties of Devon and Cornwall. The principal localities are Leemoor, Cornwood, Bickleigh, and Broomage in South Devon; and St. Stephen, St. Dennis, St. Columb, St. Burian, and Germo in Cornwall.

There are reported to be indications of kindred geological formations in County Wicklow, Ireland, but the product does not appear to have been placed on the market commercially.

Kaolinique rocks also occur in China, Japan, India, France, Germany, and the United States of America: the term kaolin itself being derived from the Chinese, Kau-ling (high ridge), referring to a mountainous region to the east of King-te-tchin, from whence the Chinese are said to obtain porcelain clay.

So far as its use in porcelain manufacture is concerned, the discovery of kaolin in China seems to have taken precedence of all other countries; but there is considerable difference of opinion as to the precise date of the discovery. (See *Handbook, Museum of Practical Geology*, 1893 ed.) Dr. Hirth is accredited with the belief that the use of kaolin was not introduced until some time after A.D. 536; and Dr. Bushell states that porcelain wares were historically mentioned for the first time in respect of the King-te-tchin potteries in the year A.D. 583.

But whatever may be the true date of the Chinese discovery of kaolin, it was certainly emulation of Chinese porcelain products that eventually led to the manufacture of porcelain in other countries, and formed the chief incentive to the discoveries of china-clay in Japan, Europe, and America.

Respecting Japan, Mr. Ernest Hart states that the rock from which Japanese porcelain was first made was discovered about A.D. 1599, as the

result of a special search in Japan by a Korean expert named Risampei, who had been brought over to Japan for this purpose. After some years of labour, it is said he found an indurated kind of kaolinique rock on the slopes of Idzumiyama. (*Jour. Soc. Arts*, 26th February 1892, p. 318.)

Professor R. W. Atkinson, B.Sc., in his *Notes on the Porcelain Industry of Japan*, refers to the results of Professor Wurtz's analyses as indicating that many of the materials used in Japan were not kaolins: "Out of eight specimens of the material used at Arita, one only, that from Kudaruyama, contained less than 74·5 per cent. of silica." Wurtz therefore concluded that "the egg-shell porcelain ware is made without kaolin, being compounded, as to its body, solely of petuntze-like or petro-siliceous minerals." But analyses by Professor Atkinson, who resided in Tokio several years, of clays from other districts, do not altogether support Professor Wurtz's conclusions. Some of the clays used in the preparation of Awata ware, and some of the Satsuma clays, evidently approach kaolin in composition, due allowances being made for differences in washing. For analyses, see list at end of this paragraph.

In Continental Europe, the first recorded discovery of kaolin is that of Schnorr, an ironmaster of Aue (Saxony), who in A.D. 1709 accidentally found a white earth which he caused to be used in the preparation of hair-powders. Eventually Böttgher became cognisant of it, and acutely surmised that it contained the necessary material for the manufacture of the coveted white porcelain. He soon succeeded in the manufacture, and, lest his secrets should become known, his king and patron practically imprisoned him at the Meissen works. Nevertheless, other discoveries rapidly followed; for, according to Hermann, a porcelain factory was set up in Vienna in 1710, and works started at Berlin in 1756, at Drankenthal in 1757, and in Thuringia 1758. (*Painting on Glass and Porcelain*, p. 15.)

In 1857 extensive china-clay works were established in Seilitz, about six kilometres from Meissen. These works are now owned by Carl Krister, of Waldenburg, Silesia, and, with the exception of the kaolin-pits of the Meissen Royal Porcelain Factory, whose mines are also at Seilitz, on the River Elbe, and Sornzig, near Mügeln, are the oldest in the kingdom of Saxony. The mining is done in proper mining fashion by shafts and galleries. The raw kaolin is in a thickness of 9 to 12 metres at a depth of 30 to 35 metres below the surface. The washing of the china-clay and grinding of the sand is done in Seilitz, and the produce is classed amongst the best existing kaolins.

The rational analysis is given as 80·93 clay substance, 15·85 quartz, 3·22 felspathic detritus; which is a higher proportion of quartz than that of washed Cornish china-clays, and possibly on that account it may be more economical to use in the manufacture of hard porcelain.

There are kaolin works also at Aue (Saxony), at Hohburg near Wurzen, at Rasephas near Altenburg, and Zettlitz near Carlsbad.

Seger gives analyses of kaolins from Ledez, Kottifen, Tremosna, Zettlitz, Lettin, Kaschfan, Sennewitz.

And Brongniart mentions Rana in Bavaria, Sosa in Bohemia, Zettlitz near Carlsbad in Bohemia, also Grisboch, Averbach, Dierndorf, and Prinzdorf, as localities where kaolin occurs.

Very recently—(July 1903)—Messrs. H. Flemming & Co., of Stettin, write that china-clay (kaolin) is found plentifully in Saxonia at Meissen, Mügeln, Bautzen, Eisenberg, etc., but not so fine and white as English.

In Bohemia, near Carlsbad, however, they say "the best kaolin for porcelain is found, and preferred to English, which is not so fat."

Some of the Rheinpfalz clays from the locality of Grünstadt have the appearance of kaolins, and burn beautifully white. And certain specimens of Westerwalder clays are very white in the native state, resembling deposited kaolin, but do not burn white.

In France, Comte de Brancas-Lauragnais, about 1758, discovered an inferior kaolinique rock near Alençon, and shortly afterwards visited England and applied for a patent for his porcelain; but as he gave no specification its exact composition is unknown. The real discovery of china-clay in France, however, was accidental; it is attributed to a surgeon of St. Yrieix, near Limoges and the date of this occurrence is given by Brongniart as A.D. 1765. The material is said to have been first used for laundry purposes. In 1768 it came under the notice of Macqueer, then director of a soft-porcelain works near Paris. Excellent results were obtained, and shortly afterwards Macqueer became associated with Sèvres, and from about A.D. 1769 hard porcelain was made there. From such accidental beginnings, and on account of the purity of the clays, a large and prosperous business has sprung up; and in many places round Limoges china-clay is obtained for use in the now numerous porcelain works that have been erected there.

Messrs. Jean Nadaud & Cie., of Limoges, inform me that the most important localities for kaolin in France at the present time are Coussac-Bonneval, Haute Vienne, and St. Yrieix. *Rousset's Directory* mentions, in addition, Daumail, Bouilly, Jouchère, Solignac, Marcognac, Eyzies, Meudon, Tain, Mehun-sur-Yèvre, Vierzon, etc.

Brongniart explains that the kaolins of the environs of St. Yrieix are generally of a fine milk-white, and friable. They are distinguished into three different qualities:—The *Caillouteux*, which is granular and friable, some of the grains being quartz-like and hard, others clay-like and tender. The *Sablonneux*, which is friable, very meagre to touch, and in which the quartz is in the state of very fine sand, but visible. The *Argileux*, which is less friable, soft to the touch, of a milk-white colour, more uniform, and capable of being made directly into a supple paste by means of water. (*Traité des Arts Céramiques*, vol. i. p. 45.) Brongniart also mentions kaolin of Louhossoa,

in the Pyrenees near Bayonne, and that of Pieux, near Cherbourg, which he observes is very argillaceous.

Seger seems to consider Limoges kaolin superior in every respect to English. He gives the rational analysis of Limoges kaolin as :—Clay substance, 96·91 per cent.; quartz, 2·32 per cent.; feldspar, 0·77 per cent. (*Collected Writings*, p. 894.)

In the United States of America china-clay was discovered prior to A.D. 1745; for there is on record a letter written by William Cookworthy, of Plymouth (England), to a Mr. Hingston, of Penryn (Cornwall), dated 30th May 1745, in which the following passage occurs :—"I had lately with me a person who has discovered the china-earth; he had with him several samples of chinaware, which I think were equal to the Asiatic. It was found on the back of Virginia, where he was in quest of mines; and, having read Du Halde, he discovered both petunze and kaolin." (*Handbook, Mus. Pract. Geol., London, 1893*, p. 128.)

Then, again, in the letters-patent No. 610, A.D. 1744, of Edward Heylyn and Thomas Frye, a substance called "unaker" is mentioned, and is described as "the produce of the Cherokee nation in America."

The Cherokis, it seems, were a branch of Iroquois Indians inhabiting Virginia and the Carolinas. (See *Living Races of Mankind*, p. 538.) And Professor C. F. Binns, when commenting on the nature of the "unaker," observes :—"This seems to have been practically identical with the kaolin used by the Chinese and by Böttcher at Meissen." (*Story of the Potter*, p. 166.)

In Josiah Wedgwood's letters to Bentley in A.D. 1766, clay from Cherokee and South Carolina is mentioned,

Mr. J. A. Holmes, in a paper read before the American Institute of Mining Engineers, October 1895, referred to kaolin "in the *Unaka* or Smoky Mountains," and he stated that it is said "to have been mined by the Indians, packed across the country to the sea-board, and shipped to England, as early as the seventeenth century."

That would seem a very early date, but it should be remembered that Virginia was discovered by Sir Walter Raleigh in 1584; and in 1676 Carolina was planted by the British. It is, however, just possible that Mr. Holmes intended to say eighteenth century, which would better accord with the evidence already mentioned.

In the course of his paper ("Notes on the Kaolin and Clay Deposits of North Carolina") Mr. Holmes explains that "As the Appalachian Mountains reach their maximum development in Western North Carolina, we find . . . . indications of extensive dynamic disturbances. . . . . Among the minor results of these changes have been the formation of numerous dikes or veins of exceedingly coarse granitic material, which in some places are mined for the mica which they contain, and in other places are quarried for kaolin. These

dikes are filled with quartz, feldspar, and mica, in varying proportions, very coarsely crystallized. . . . . This feldspar of the dikes undergoes, through the weathering action of the atmosphere, certain chemical changes, resulting in its alteration from feldspar to kaolinite—the kaolin of commerce. These dikes vary considerably in size, ranging from a few inches to several hundred feet in thickness, and up to many hundred yards in length. They are generally parallel to the schistosity of the crystalline rocks, which, however, in some cases they cross at varying angles. The kaolin in those dikes which occur in the Unaka or Smoky Mountains is said to have been mined by the Indians, packed across the country to the sea-board, and shipped to England, as early as the seventeenth century. From one of them, near Webster, in Jackson County, kaolin is now mined [by the Harris Clay Co.], and shipped to Trenton, N.J., and other centres of the manufacture of fine pottery." (*Trans. Am. Inst. M.E.*, vol. xxv. 1896, p. 929.)

Thus the discovery and identification of china-clay, as such, in the United States of America takes precedence over that of England.

Whether the American-Indian, the Cornish smelter, or possibly the Phœnician tin-miner was the real pioneer in its discovery for other purposes must ever remain a subject of uncertainty.

Other evidence of the shipment of American kaolin to England in the eighteenth century is found in the record that "Mr. Caleb Lloyd, residing in Charlestown, South Carolina, in November 1765, sent a box of kaolin to Bristol, to be forwarded to Lord Hyndford, who was a relative of both Champion and Lloyd. The result of the experiments on it was related by Champion to Lord Hyndford under date 28th February 1767." (*Handbook, Mus. Pract. Geol.*, p. 131.)

Kaolin evidently had been discovered in Wilmington (Del.) considerably before 1854, for Brongniart mentions the kaolin of Wilmington, and describes it as "BLANC, CAILLOUTEUX, FRIABLE, MAIGRE AU TOUCHER." (*Traité des Arts Céramiques.*)

More recently, along with the growth of the white pottery industry in the States, there has been a development of American kaolin deposits. At Dillsboro in North Carolina, for example, the Harris Clay Co. have a large mine. C. J. Harris, Esq., president of this company, informs the writer that their kaolin lies in veins more or less vertical, and situated in a geological formation which he believes to be azoic, viz., one of the oldest in North America; the china-clay in some other parts of the United States being only secondary deposits, mostly sedimentary and in horizontal beds.

In some places the vein of clay worked by the Harris Clay Co. is 300 feet wide; this is exceptional, even in Carolina, where the veins seldom exceed 20 feet wide, and many veins are too small to pay to work. The veins become harder at a depth of about 100 feet, and assume the character,

we understand, of a rock of flint and felspar only partly decomposed. The Harris Co. started working about thirteen years ago. It is claimed that the output of this particular grade of clay in the States is confined to North Carolina, and that it will not exceed about ten thousand tons a year. The following is an analysis of the product:—Silica, 46·47; alumina, 38·14; ferric oxide, 0·36; lime, 0·50; magnesia, 0·09; alkalies, 0·64; combined water, 13·61.

Dr. Heinrich Ries, in his recent work on *Clays of the United States East*

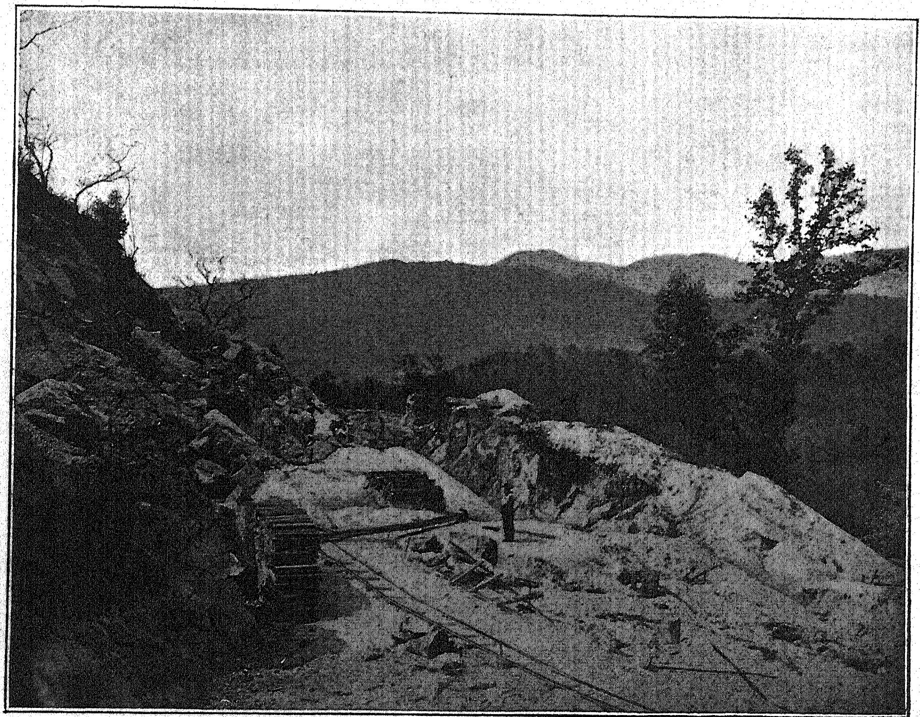


FIG. 156.—Kaolin-mine, Dillsboro, N.C.

of the Mississippi River (p. 38), states that Harris Clay Co.'s clay from Webster, N.C., "works up with 42 per cent. of water to a lean mass. Air-shrinkage, 6 per cent.; fire-shrinkage, 4 per cent. . . . . incipient fusion, 2300° F.; vitrification at 2500°; viscosity above 2700°. Burns white."

Dr. Ries also mentions kaolin at Thayer, Davidson County, N.C., which "works up with 23 per cent. of water to a lean mass, whose air-shrinkage is 3·2 per cent. and fire-shrinkage 3·3 per cent. . . . . Incipient fusion at 2300° F., complete fusion at 2600°. . . . . Fluxes, 2·36."

The fluxes mentioned by Dr. Ries seem rather excessive for kaolin, and

the Thayer clay would possibly be of a denser and more vitreous nature than many china-clays are.

In the State of Georgia, at Macon or near, a deposit of kaolin is being worked, which apparently is of sedimentary nature. The Irwin Clay and Sand Co. of Chicago (Ill.), who, the writer understands, are agents for certain Georgia clays, report that their mines are located at Dry Branch, Georgia, on the Macon, Dublin, and Savannah R.R. The deposit there is very thick and of even quality, and at least one hundred thousand carloads are said to be in sight.

A report upon the physical properties of this clay, by Dr. Heinrich Ries, of the Department of Economic Geology, Cornell University, Ithaca, N.Y., dated 3rd February 1902, reads as follows:—"The material is a soft, very fine-grained clay, which is nearly white in colour in its green condition, and remarkably free from grit.

"When worked up into a plastic mass it takes 21 per cent. of water, and develops a plasticity which in feel is very nearly equal to that of Florida ball-clay. The air-dried briquettes made from this mixture have a tensile strength of 50 to 55 lbs. per square inch, which is higher than that of many Jersey ball-clays, and nearly equal to that of the Florida ball-clay. The air-shrinkage of the material was 5 per cent. When burned up to Cone 5, the colour of the material is white, and the total shrinkage 10 per cent. If heated still higher, or up to Cone 10, which is higher temperature than that attained by most white earthenware manufacturers, the total shrinkage is 15 per cent., and the colour white with but the merest tinge of yellow, in fact so small as to be almost imperceptible. The clay burned up as high as Cone 8 without showing any yellowish tint. In burning the clay by itself it shows a tendency to develop some small cracks, but these are much less numerous if the clay is lawned before molding. The material is highly refractory, for when heated to a temperature of 3100° F., in other words, a dazzling white heat, it shows no sign of fusing."

The Georgia Kaolin Co., of Macon (Ga.), appear to work mines in the same district, and Mr. I. Mandle, of St. Louis (Mo.), has very kindly sent the writer some notes relating to "Sant's No. 1 Georgia china-clay." This also appears to have been examined by Dr. Heinrich Ries with equally favourable results. The rational analysis is given as follows:—

Clay substance, ...	99·00 per cent.
Quartz and feldspar, ...	1·00 ,,

Hence, although apparently a sedimentary deposit, the product must be of excellent quality.

Results of physical tests are:—Tensile strength, 55 lbs. per square inch. Slakes rather readily in water. The entire amount passes through a screen of

150 meshes to the inch (presumably when in intimate suspension in water). The most plastic kaolin in existence (which is certainly saying a lot, considering the plastic kaolins of Germany). Air-shrinkage, 6 per cent.; on burning up to Cone 5 an additional 5 per cent., and at Cone 8 a little more.

In addition to the Georgia Kaolin Co. there are several other companies who are working mines in the same district, but their product is said to be sold principally to paper mills; except I. Mandle & Co., who sell their entire output to the pottery and encaustic tile trades. Georgia china-clay is reported to be equal to French clay, and an experienced American manufacturer assures the writer that he considers Georgia kaolin the best of its kind in the country for pottery or tiles.

Referring again to Mr. J. A. Holmes' interesting and instructive paper, he states that "At various points in the Piedmont Plateau, which extends east of the Blue Ridge for from one hundred and fifty to two hundred miles, there are to be found deposits of this kaolin which have doubtless originated in much the same way as those west of the Blue Ridge; but none of those are now worked to any considerable extent. The age of the crystalline rocks in the Piedmont Plateau and the mountain counties, and the exact time at which the disturbance took place which resulted in the formation of these massive granite dikes, is, as yet, a matter of doubt.

"So numerous are these dikes in certain places, and so long have their feldspars been undergoing surface-transformation to residual kaolin or clay, that one might expect to find in this region, as in some other countries, sedimentary deposits of this material which had been transported for greater or lesser distances; but when we bear in mind the general elevation of the mountain region, and the consequent rapidity of its streams, we can readily understand that this product of decay and denudation would scarcely be deposited until it had been carried so great a distance from the original source as to be lost by commingling in the lowlands with larger portions of other and different materials. . . . . Along the borders of Piedmont Plateau region there are occasionally found deposits of this kaolin material, which has evidently been carried but a short distance. Such occurrences are more extensively known on the western border of the coastal-plain region, mainly in the Potomac formation, as in the neighbourhood of Aiken, S.C., and Augusta, Ga., and in many other places where considerable deposits of this kaolin material occur, both in the form of arkose (where the kaolin is still mixed with the quartz and mica of the original granitic formation), and in the clay-beds where it has been more completely sorted, and the kaolin has been separated from the coarser materials, so as to form extensive beds of what is locally termed 'china' or 'potter's' clay. In some cases, in the arkose material just referred to, the partially decayed crystals of feldspar are frequently found with kaolinization incomplete; and mingled with these are

fragments of other minerals, transported from the *débris* of the crystalline rocks occurring along the borders of the Piedmont Plateau, not many miles away. . . . . Through many places, in both the mountain and the Piedmont Plateau regions, there are deposits of clay resulting from the decay of the granites, gneisses, and crystalline schists. Many of these have a structure which would indicate that the materials have been transported . . . . but in perhaps many other cases the materials have evidently decayed in place, since the gradations can be traced from the clay down into the partly altered rocks below." (*Trans. A.I.M.E.*, vol. xxv. p. 936.)

For a typical native American kaolin, Professor Binns takes that of Hockessin Valley, Delaware, of which he gives the rational analysis thus:—

Clay substance, ...	90·42
Quartz, ...	6·08
Feldspathic matter, ...	3·50

(See *Transactions, American Ceramic Soc.*, vol. v. p. 281.)

The writer is informed that the largest and oldest clay-miners in Delaware are Golding & Sons, whose mines are situated at Hockessin (Del.). This clay is known to the trade as "Golding china-clay." It is washed before being marketed, and both in its crude and its washed condition possesses a yellowish tint; yet when fired up to Cone 8 it becomes fairly white, and is, in fact, one of the most popular United States china-clays on the market for pottery purposes.

The entire output of Delaware is estimated by Mr. Mandle to be fifteen thousand tons per annum. Dr. H. Ries mentions both Hockessin and Newark (Del.) as localities where china-clay is found, and he gives some interesting photographs of one of the kaolin-pits, and of a washing-plant at Hockessin, operated by Mr. J. T. Burgess.

With regard to the kaolins of Florida, Dr. H. Ries, under the classification of "*Ball-clay*," tells us that "It occurs at several points in the north-central portion of Florida. . . . . It is undoubtedly of sedimentary origin, and the occurrence of such an extensive deposit so free in most places from impurities is remarkable. The mass is made up of a mixture of white clay and quartz pebbles, the latter forming 65 to 75 per cent. of the entire mass, so that for every ton of washed clay about four tons of the crude material have to be mined. The quartz pebbles vary in size from that of a pinhead to a diameter of three-quarters of an inch. The largest ones seem to occur chiefly at the northern end of the area in which the kaolin is found. . . . .

"The largest pit which was being worked at the time of the writer's visit [Dr. H. Ries] was that at Edgar, Fla., which is about fifty miles south-west of Jacksonville. . . . . Another but more extensive area of this clay occurs along the Palatlakaha River, south of Leesberg, Lake County. This large

FIG. 157.—Kaolin-pit near Hockessin, Del., U.S.A., showing drift over kaolin and the starting of a circular shaft. (*By permission of the United States Geological Survey.*)

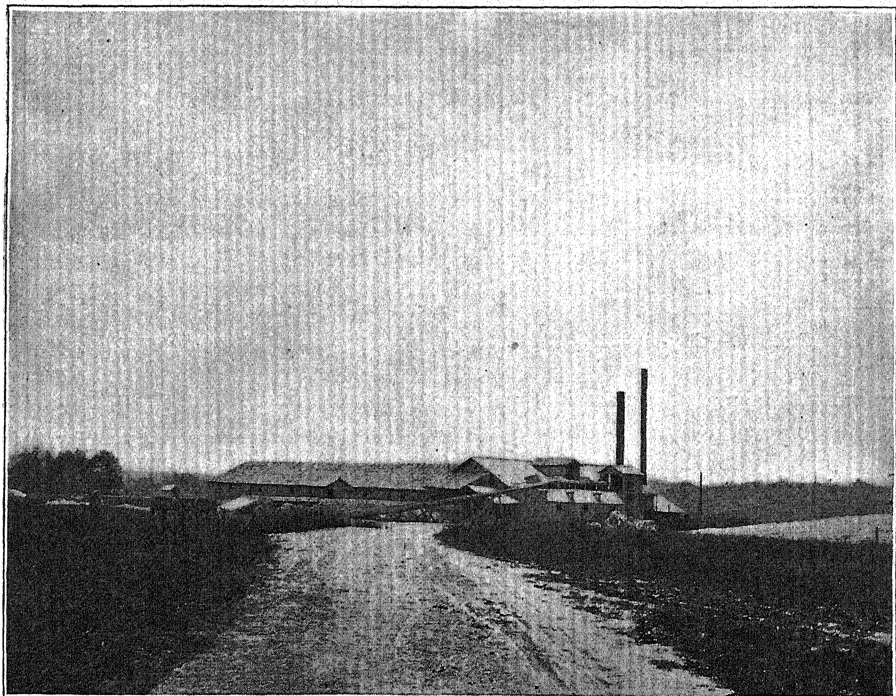


FIG. 158.—Kaolin-washing plant of J. T. Burgess, Hockessin, Del., U.S.A. (*By permission of the United States Geological Survey.*)

tract begins one mile south of Lake Harris, into which the Palatlakaha River flows, and extends along both sides of the river nearly to Villa City.

"Throughout this belt there is an overburden of 3 feet of loose sand, under which lies the white ball-clay, of a depth varying from 10 to 30 feet. . . . This deposit has been opened up at a point four miles south of Leesburg, where it is said to be 25 to 30 feet thick. Another area of this same clay occurs at Barton Junction, Polk County, about forty-five miles north-east of

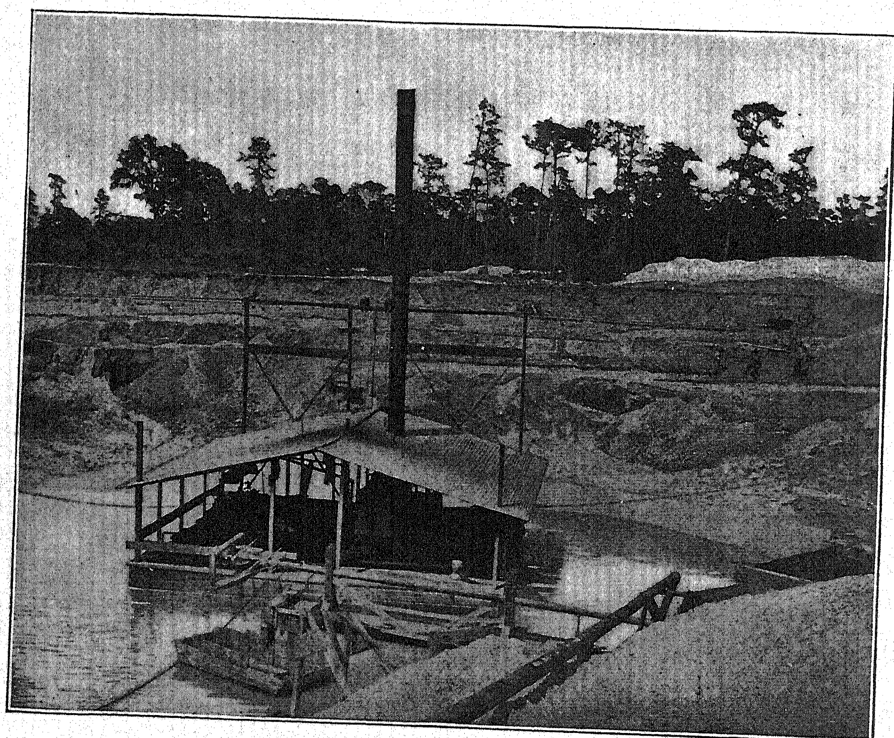


FIG. 159.—Clay-pit at Edgar, Fla. (*By permission of U.S. Geological Survey.*)

Tampa. The sandy character of the raw clay permits it being worked by a method somewhat different from that usually practised at most kaolin-mines. At Edgar the pit is filled with water, and on this there is a float carrying a scraper and pump. The former loosens up the clay in the bottom of the pit, and the latter draws it up to the surface and discharges the water, with suspended clay and sand, into the washing-troughs. Owing to the fact that this Florida clay is very plastic, it is put on the market under the name of ball-clay. It is very refractory and burns white. In the table below are given chemical analyses of the clay from different points. It differs from the

English ball-clay chiefly in its greater refractoriness, and also somewhat in its plasticity. . . . .

ANALYSES OF FLORIDA BALL-CLAY.

	(1)	(2)
Silica,	46·11	45·39
Alumina,	39·50	39·19
Ferric oxide,	·35	·45
Lime,	...	·51
Magnesia,	·13	·29
Alkalies,	...	·83
Water,	13 78	14·01
Sulphur trioxide,	·07	...
	99·94	100·67

(1) Washed clay from Palatlakaha River.
(2) Washed clay from Edgar.

(*Clays of the U.S. East of the Mississippi River*, pp. 82, 83.)

Langenbeck also refers to these Florida clays as "native ball-clays." (See *Chemistry of Pottery*, p. 100.) And Professor Orton, jun., of Columbus, describes them as white clays which have been transported over long distances and redeposited as secondary beds. (See *Trans. Am. Ceramic Soc.*, vol. v. p. 379.)

Even Professor Binns refers to Florida clay as a type of washed ball-clay containing over 98 per cent. of clay substance.

Against the mature opinion of such a group of distinguished American scientists, it will appear presumptuous on the part of an Englishman to venture a contrary opinion; yet the writer feels constrained to do so, being convinced that these Florida clays, as described in American literature, do not exhibit the natural characteristics of whiteware potter's "ball-clay," using the term in the sense it is understood in Great Britain, nor even in the sense it is used by stoneware potters.

English "ball-clays" are rarely washed, and, when they are, it is for a very different reason than applies in the case of Florida clays. The fact that, in their native state, Florida clays contain 65 to 75 per cent. of coarse quartz is a phenomenon immediately differentiating it from ball-clay.

On the other hand, virgin china-clay rock or carclazite of Cornish origin contains from three to seven tons of sandy quartz to every ton of fine clay (*Jour. Soc. Arts*, 5th May 1876); and that very closely corresponds with the proportions of quartz in native Florida clay previous to washing.

Comparison of specimens of native English blue ball-clay (rarely a washed product), washed Cornish china-clay, washed Florida plastic kaolin before burning, and of these same series of clays after burning in a potter's kiln, at once, in the opinion of the writer, assigns the Florida product to

the "*china-clays*" rather than to the "*ball-clays*," using these terms in the sense generally accepted in Staffordshire.

Chemical analysis likewise indicates the same classification, by reason of the low percentage of alkalies in the Florida washed clay, viz., 0·83 per cent.

Someone may point out that, on p. 38 of *Clays of U.S. East of the Mississippi River*, Dr. Heinrich Ries gives the total fluxes of Edgar (Fla.) clay as 5·15 per cent. But, although Dr. Ries cites Langenbeck (*Chem. of Pottery*, p. 101) in support of this, I find nothing in Langenbeck, at the page given, of the nature assumed. Indeed, on p. 100, *C. of P.*, Langenbeck gives the alkalies 0·83, and iron, lime, and magnesia together 1·25. A mistake has apparently been made by the learned doctor, which will be evident to anyone comparing his remarks a few lines higher on p. 38, and his analyses on p. 39.

For these reasons the writer cannot concur in classifying the Florida clays as ball-clays, but agrees with the proprietors of the Florida mines, who apply a peculiarly appropriate and correct denomination to their product, viz., "*plastic kaolin*."

Hence it has been included in this notice of American china-clays.

The foregoing remarks must not be assumed to be in the slightest degree derogatory to the Florida clays; for undoubtedly they are remarkably useful clays, only awaiting greater enterprise, skill, and opportunity to enable their use to be vastly extended, if supplies hold out. Indeed, many British potters would be glad if similar clays were at their service.

In the State of Missouri a material termed china-clay is mined near Glen Allen. This is washed and put on the market in washed condition. The colour is white, the clay mixes well with water, and when screened through a 120-mesh sieve leaves no residue.

The rational analysis is given by the proprietor, I. Mandle, Esq., of St. Louis (Mo.), as under:—

Clay substance, ...	53·10
Feldspar, ...	3·65
Flint, ...	43·25

It is said to possess the average plasticity of kaolins, but it cannot be practically used without the addition of ball-clay. When moulded and dry it does not bear any handling, while in mixture with ball-clay it is not sensible as to this point. The total shrinkage of this china-clay at a Cone 8 heat is 11 per cent. At this temperature it burns to a white open body.

In testing with pottery bodies it was found that this china-clay can be used to a higher percentage in mixtures than the average kaolins, without injuring the colour and quality of the ware. It can be used to advantage in making bodies for many pottery purposes, when due allowance is made,

in accordance with its composition as per rational analysis. It is thus classed as a good white kaolin of a highly siliceous type. And although its analysis is very different from that of average kaolin, any well-trained ceramist will see in it very useful qualities.

In New Jersey State there are very persistent beds of what seems to be sedimentary kaolin, in the clay-beds at the mouth of Raritan River. Dr. Cook has described them and given chemical analyses; but either from impurity or from high siliceousness, or yet, again, possibly from want of enterprise, these clays do not seem to be washed as china-clay for white-ware potters.

A white clay, dug within about three miles of Trenton, is mentioned on p. 235 of Dr. Cook's 1878 report, but he adds: "All of these clays are carted to Trenton, and used principally in the potteries in making saggars." Dr. Cook mentions that in a narrow valley one and a half miles south-west of Bethlehem, Hunterdon County, Northern New Jersey, a kaolin *in situ* was discovered about 1872. Some of it was washed and tested at Trenton, but was found to burn of too dark colour for use as porcelain clay.

In Pennsylvania kaolinique rocks of siliceous white clays, possessing valuable and peculiar vitreous qualities, and containing appreciable percentages of magnesia, occur in the south mountains of Cumberland and York Counties. At Mount Holly Springs, about twenty-eight miles south of Harrisburg (Pa.), an estate was opened up in 1897, and a company organized for the purpose of refining the clay for use in the manufacture of wall-papers and white vitrified bricks. The refining process adopted was what is known as the floating process, by which the slip is allowed to run through long troughs into settling-vats, where the fine sand is allowed to settle and the clay then pumped into filter-presses, from whence it is taken to the dryer, and, after being dried, is ready for shipment.

Large quantities are said to be used by floor-tile and wall-tile manufacturers. The chemical analysis of the refined clay is given thus:—

Silica,	63·17
Alumina,	22·20
Oxide of iron,	0·31
Lime,	0·05
Magnesia,	3·08
Water of combination,	4·97
	93·78

The unaccounted-for percentage possibly may be water of hydration.

The crude clays, just as taken from the clay-bank, are manufactured into white vitrified impervious bricks that are finding great favour with prominent architects, some twenty thousand bricks daily being put on the market.

Of very similar nature, it would appear, is the material operated by The

Chesnut Ridge White Brick Co., of Chesnut Ridge (Pa.). This company, about three years ago, purchased mineral rights on nine hundred and thirty-seven acres of land in the Blue Ridge Valley, Monroe County. This deposit of clay varies in colour from white to buff, producing chiefly a vitrified brick of marble whiteness, of which, it is said, some two millions were used in the Ansonia Apartment Hotel, Upper Broadway, New York City.

The clay is raised from open workings, and loaded into the buckets of a conveyor. These buckets run on a stationary cable, and are drawn by an endless wire-rope; there is a down-grade from mine to works, where storage capacity is provided for ten thousand tons.

At Ore Hill, near Hollisdayburg (Pa.), a sandy kaolinique rock is quarried, and sold for use in making saggars, stilts, tiles, and the like. Apparently this material has not been very scientifically or technically examined at present; but, judging by inspection of sample, there are the elements of good kaolin in it, only awaiting suitable treatment by sedimentation processes, and subsequent skilful use in a technical sense. In one instance, where this clay is in use for tilemaking, the writer is given to understand that the clay is washed at the tileworks before use.

As to Virginia, Langenbeck mentions kaolin from Nelson County which yields on analysis:—

Silica,	50·02
Alumina,	35·18
Ferric oxide,	0·36
Lime,	0·12
Magnesia,	0·07
Alkalies,	3·39
Combined water,	10·57
	99·71

This refers to a kaolin which is found native in such a naturally fine state of division as not to require separation of portions by floating and sedimentation, but may be used directly in a whiteware body. (*Chemistry of Pottery*, p. 94.)

Some compensations would clearly have to be made for the high percentage of alkalies, which seem to indicate the presence of feldspathic substances in a finely divided state.

Mr. Mandle kindly writes that "Although there is little doubt that Josiah Wedgwood used china-clay from Virginia in the first whiteware made by him, the deposits in that state have never been worked until July 1902. The Blue Ridge Kaolin Co. commenced mining operations at Oak Level, Henry County (Va.), putting up a washing-plant of a capacity of three hundred tons a month, which is now in full operation, with a ready demand for its output. This deposit is located in a spur of the Blue Ridge Mountains, and the crude

ore is exactly similar to that of Dillsboro (N.C.), though the form of the deposit is different, being found in a blanket vein extending over many acres. Other large deposits of a similar character are known to exist in the State of Virginia, but at present this is the only one in operation."

More recently kaolin is said to have been discovered at Jonca, near St. Genevieve (Mo.), but only experimental quantities seem to have been raised and tested at present; and the results of its commercial exploitation must necessarily be awaited with some degree of anxiety by those concerned in the adventure.

As to Wisconsin, Dr. Ries mentions white-burning sedimentary clays occurring at Hersey, St. Croix County, also in the valley of the Eau Claire River. Large quantities are said to be washed annually and sold to paper-makers in Minnesota and Wisconsin.

South Carolina yields plastic clays, called china-clays, which are marketed without washing, and are used, it is said, mostly for wall-paper and linoleum.

In Texas, too, clays of good quality are reported to exist, but their commercial inaccessibility renders them for the present uninteresting.

Connecticut, Vermont, Wisconsin, Maryland, Massachusetts, and Pennsylvania are also mentioned by Dr. Ries as sources of clays of the nature of china-clays.

In the map, p. 284 of *Clays of the U.S. East of the Mississippi River*, Dr. Ries marks two localities near Roanoke in Alabama as possessing kaolin deposits; also one locality near Shoals in Indiana. But Dr. Ries (p. 48) refers to Indiana clays as occurring in pockets in carboniferous limestone; this raises a doubt as to their being genuine kaolins.

In Canada, so far as the matter has yet been officially reported, kaolin deposits or formations appear to be very limited, the only notice of such apparently referring to an almost inaccessible region on the Hudson Bay slope; and of this Dr. Robert Bell, Director of the Geological Survey of Canada, states that, although the light-coloured clay found upon the Missinabie River was thought to be kaolin, it proved to be only a good quality of ordinary clay.

In England the first discovery and identification of this coveted rock is, by general consent, attributed to William Cookworthy, a native of Kingsbridge, in Devon, about A.D. 1750 to 1754. The discovery in this instance cannot be justly characterized as chance or accident; for, as a chemist, Cookworthy had evidently become deeply interested in the subject of the manufacture of porcelain. Probably he had heard of the report by Père d'Entrecolles, who in 1712 resided at King-te-tchin, and made known the nature of the materials used in the manufacture of Chinese porcelain, and sent samples to Paris in A.D. 1727–1729. (*Handbook, Mus. Pract. Geol.*, 1893.) No doubt he had learned also that suitable clay had been found in Saxony in

1709, and that Böttgher had succeeded in making porcelain at Meissen. He would possibly know, too, that works had been established at Vienna, Höchst, Berlin, and Bavaria; and that a certain sort of porcelain was made at Chelsea. Dr. Wall's success at Worcester afterwards coming to his knowledge would be another incentive.

His engrossment in the subject was apparently well known, for as early as 1745 he refers to a visit of someone from America, with specimens of ware purporting to be made of American kaolin; indeed, Collins says that his works was first established at Plymouth in 1733. (*Jour. Soc. Arts*, 5th May 1876.)

A detailed description of Cookworthy's search for kaolinique rocks (from his own pen) may be found in Jewitt's *Life of Wedgwood*, p. 227, etc., whence we learn that he had for years been beset with a yearning for its discovery in England, and that he doggedly persevered until first at Tregonnin Hill, then in the parish of St. Stephen's, and afterwards in Boconnoc, the object of his quest was found.

British whiteware manufacturers of to-day, who, week in and week out, are dunned for orders for china-clay, may find it hard to appreciate the intensity of desire that burned in the thoughts of ceramists of the eighteenth century for the discovery of a material to enable them to rival the productions of the Chinese. But Cookworthy did more than merely find the materials; he promptly applied himself to the difficult task of manufacturing the newly found materials into porcelain wares, for Staffordshire potters knew nothing of this at that period, and could give him little help. By dint of dauntless perseverance he eventually succeeded; and has explained that for the body of the ware he "generally mixed about equal parts of the washed caulin and petunse," and for the glaze "the stone . . . . for glazing are those with the green spots of Tregonnin Hill. These, barely ground fine, make a good glaze." In 1768 he secured a patent for the use of Cornish clay and stone, and manufactured it into porcelain at Plymouth, availing himself of the services of a talented artist to decorate his wares; but the venture was not a financial success, and in 1773 William Cookworthy sold the patent rights to Richard Champion, of Bristol. Nevertheless, his discovery has been a gigantic financial success to the British nation, and demands of us a passing tribute of respect to Cookworthy's genius and persistence.

Another name deserves remembrance in connection with the practical introduction of Cornish clay, namely, that of Richard Chaffers, of Liverpool. Born 1731, this gentleman, Mr. Mayer, the accomplished historian of Liverpool pottery ware, tells us, served his apprenticeship with Alderman Shaw; after which, about 1752, he commenced business on his own account at a works near the bottom of the Brow, Liverpool. At first he made the usual blue and white "Delft" earthenware; but, subsequently hearing of the great improvements

by Wedgwood, Mr. Chaffers determined to make a higher class of ware, and set about seeking materials for the production of china. About this time he became acquainted with a person named Podmore, formerly an employee of J. Wedgwood, and induced him to become his manager. Finding that the lands upon which Cookworthy had discovered china-clay, or, as Mayer calls it, "soapstone," had been leased to other persons, Chaffers decided to set out for Cornwall in the hope of discovering some for himself. He obtained letters of introduction to several of the leading landowners of Cornwall, then in London, and then set out on his journey, which in those days, when there were neither mail-coaches nor railways (see *Art of Pottery*, p. 68), was a task of horsemanship of no mean order. After great expense and disheartening disappointments, his first efforts proved unsuccessful, and he paid his men and turned again dispirited towards home. One of the men, however, was not present, and Mr. Chaffers was told he had gone up the mountain to try another place. After journeying some distance homeward, Mr. Chaffers heard a faint cry, and, turning to inquire its cause, observed the preconcerted signal of discovery flying from a lofty peak. Mr. Chaffers then returned again, re-engaged the workmen, and thenceforward obtained an ample supply of the long-sought clay, which was ultimately shipped to Liverpool.

On his return journey from Cornwall, Chaffers was struck down by a dangerous fever while in London; but he recovered, and upon arriving again in Liverpool he set to work with his new materials, and soon produced ware of such excellence that even Josiah Wedgwood is said to have frankly acknowledged its superiority.

The pathetic termination of Chaffers' promising life is briefly told by Mayer as follows:—"Podmore, his favourite foreman, was seized, some years after the events narrated, with a malignant fever, without hope of recovery. The unfortunate sufferer sent a message declaring his wish to see his dear master once more before their final separation. Mr. Chaffers . . . . imprudently complied, and shortly after took the fever to which he fell a victim. He was interred in the old churchyard of St. Nicolas, near the grave of his faithful servant. . . . . This unfortunate event, by taking away both master and faithful assistant, put an end to the prosecution of the trade." (*History of the Art of Pottery*, p. 70.)

The discovery of some of the deposits around St. Austell is usually accredited to Robert Robins Geach; in 1820 he is said to have sold clay at £5, 10s. a ton, and in 1821 at £4, 10s., the quantity in the latter year being two hundred and twelve tons.

Thomas Minton, founder of the great firm of MINTONS, china and earthenware makers, Stoke-on-Trent, also had a little experience in mining china-clay in Cornwall about A.D. 1800 to 1820. Jewitt relates the incidents of this attempt to conduct clay-mining at Hendra Common, about three miles

from St. Austell, by Minton and some associates. (See *Ceramic Art of Great Britain*, p. 190.)

The Cornish output of china-clay for all purposes gradually increased, until in 1901 it reached the aggregate of 463,504 tons, supplemented by an output of 54,064 tons from Devonshire. But it should be remarked that by far the greater portion of this output of china-clay is used in other industries, such as the linen, cotton, and paper manufactures; probably not more than a tenth part of the whole being used by potters.

In Denmark kaolin occurs on the island of Bornholm, near the port of Rönne, but the quality is reported to be not fine enough for the production of china or porcelain. This Bornholm clay product is used mostly for paper-making, and for refractory products, including potters' saggars. Messrs. H. Flemming & Co., of Stettin, inform the writer that about four to five thousand tons are annually shipped from Bornholm to Germany for "*Chamotte*" (burnt fireclay) purposes.

Rönne is the capital town and port of Bornholm, and there are numerous pottery works on the island.

In Portugal valuable deposits or formations of kaolin are said to exist in the neighbourhood of Oporto. (See *British Clayworker*, September 1903, p. 221.)

In Persia, at Vartoon, near Ispahan, something of the nature of kaolin appears to be found.

In India china-clay is said to be found not far from Delhi, and is used by gold and silver smiths for crucibles; but Delhi whiteware potters, it is said, do not use it, preferring to use almost pure sand.

Mr. C. J. Hallifax, C.S., the authority for the foregoing, adds that kaolin is also found in the Himalayas, particularly in the Mandi state.

Dr. Alex. Hunter, M.D., F.R.C.S.E., in a report upon his attempts at improving Indian pottery manufactures, tells us that, on looking over a large collection of minerals and clays found in various parts of the Madras Presidency, he was struck with the great abundance of the white granites, felspars, kaolins, or porcelain earths and siliceous or flinty rocks, many of them procurable in exhaustless profusion.

In New South Wales kaolin is reported to have been raised, during the year 1902, in quantity from deposits at Ulladulla, Tichborne, and Gosford. (*Ann. Rept. Dept. Mines N.S.W., 1902*, p. 59.)

In Queensland, Brisbane district and Rockhampton are reported to have been the subjects of a good deal of prospecting for clay some years ago.

In Victoria kaolin is said to be mentioned in the *Annual Report relating to Mines and Water* as being raised in the colony.

Preparation.—Unlike other clays already noticed, china-clay, as it appears in commerce, is a product resulting from most careful and elaborate treatment of the native rock. The process varies slightly according to the particular

situation and surroundings of the mine or "sett"; the degree of purity and excellence of quality to be attained; and the volume or quantity it is desired to raise and prepare for sale.

Four principal operations are necessary, namely:—

(1) Breaking down the rock or native clay from the stopes.
(2) Separation of the coarse quartz crystals or sand.
(3) Refining from coarse clay and micaceous scales.
(4) Settling, decanting the water, drying the clay.

With regard to preliminaries, David Cock writes:—"When the general aspect of the locality is sufficient to produce confidence in the mind of the explorer that there is a bed of clay beneath the surface, he immediately takes steps to test it. For this purpose he sinks a pit through the soil until it reaches the suspected clay. This pit, of course, is of no certain depth, as the overburden is sometimes only a few feet thick, while at others it is five or six fathoms in thickness. . . . When the pit has reached the clay, the object of testing its existence is answered, but the pit is still continued to ascertain the thickness of the bed and the depth of the clay. A sample of the clay is then taken, in order to test its quality. . . . If the test turns out to be satisfactory, several other pits are sunk to ascertain the area of the deposit; and if the depth, quality, and area of the clay are sufficient to warrant its being worked, preparations are immediately made to open up the ground and to get the mine in working order." (*A Treatise on China-Clay*, by David Cock, p. 29, Simpkin Marshall & Co.)

Kaolin or kaolinique rocks do not always yield products saleable as china-clay. Brongniart names several localities in France where this has happened; among others, that of Alençon, the first of the kaolin discoveries in France; and similar instances arise at Neuvic-sur-l'Isle and Westerwald. Hence, as David Cock very wisely proceeds to say:—"When the clay is taken out of the trial pit, the first care of the miner is to test its quality. The methods adopted for testing are various, and depend much on the purposes to which the clay is intended to be applied. If it is tested with a view of ascertaining its value for the manufacture of porcelain or pottery, it is first carefully washed in the following manner. The virgin clay having been pulverised, and thoroughly mixed with water, the gravel and grit are allowed to settle . . . . whilst the clay is left in suspension. The combined clay and water are now poured into another vessel and allowed to remain till the clay is precipitated, and the water is again poured off, so that nothing but the clay remains. The clay is then dried at a gentle heat, and afterwards submitted to a severe test by fire. Strength and whiteness are the most important desiderata in this case." (*Ibid.*, pp. 29, 30.)

The mode of working in 1807 has been described by Dr. Fitton; and as

this may be of service in cases where it is not at first desired to erect expensive engines and machinery, it is repeated here:—"The overburden being removed to a considerable extent, the clay itself is dug progressively in steps, the discoloured portions being picked out and thrown away. The selected clay is then wheeled to the washing-place or 'strake,' and washed with a stream of water. A large quantity of 'sand' is at once separated, and this is shovelled away continually. The clay and finer mica is carried on by the flowing stream to 'pits' and 'ponds,' which are rectangular receptacles built of rough stone, cemented by lime; the pits 5 and 6 feet in the side and 4 feet deep, the ponds 20 feet by 12 feet and the same depth. The first pit receives the fine sand and coarser mica; the second and perhaps the third the fine mica, while the fine clay settles in the last or passes on to the ponds. When the ponds are full, their contents are transferred to shallow 'pans' lined with granite, about 40 feet by 12 feet and 14 feet[1] deep. In these pans it remains from four to eight months, often from September to the following May. It is by that time stiff enough to cut up into square blocks, which are further dried by exposure to the sun, scraped, and rammed into casks. The scrapings and waste are wheeled back to the strake and rewashed. . . . ."

Mr. Henwood's account adds to the above . . . . that when, during rainy weather or from any other cause, the clay does not settle, it is watered with a solution of alum from a common watering-pot. (*Jour. Soc. Arts*, 5th May 1876.)

By the old method, *i.e.*, without pumping machinery, when the situation of the clay is on a hill, an adit-level is driven through the hillside, starting from a place convenient for sand-pits and waste-tipping, and terminating in the clay-sett at the level of the bottom of the intended workings, sufficient overburden having been removed to prevent contamination.

The decomposed rock or virgin clay is carefully broken down from the "stopes" or quarry-sides, and separated from any intrusive veins of schorl or of tin-ore; and sometimes selected into several qualities, if these occur in the sett naturally. These are separately broken down, and deposited some distance from the sand-pits or trenches, and there subjected to the action of a strong force of water, being occasionally dug and turned about while the stream flows through its mass. This stream of water extracts and conveys the clay in suspension into a trench-like structure about 10 feet by 4 feet by $4\frac{1}{2}$ feet, arranged so as to obstruct and detain by deposition or subsidence all coarse quartz-crystals or fragments of rock of any kind, the exit from the trench being an opening at the base protected by a grid, through which the water with the fine suspended clay exudes. Two or more of these sand-pits or troughs may be arranged abreast, so that the stream may be turned and operations continued whilst the accumulation of sand and detritus is removed from the one already full.

[1] Query—inches.

The exuding clay and water stream, now containing probably $2\frac{1}{2}$ per cent. of clay substance, flows by means of channels or pipes towards the refining apparatus—*i.e.*, the mica-drags, shell-traps, depositing pits and ponds, and drying-sheds. These should be erected at some convenient place adjoining a road, railway, or seaport.

The mica-drags or "shell"-traps are long, flat, low-sided wooden troughs, measuring about 20 feet by 12 inches by 8 inches, arranged in series side by side, each trough or channel having an inverted sluice, acting upward in sections at the outlet, which can be raised little by little as the deposit accumulates. Upon approaching the *drags* or *catches*, the speed of the clay-stream is

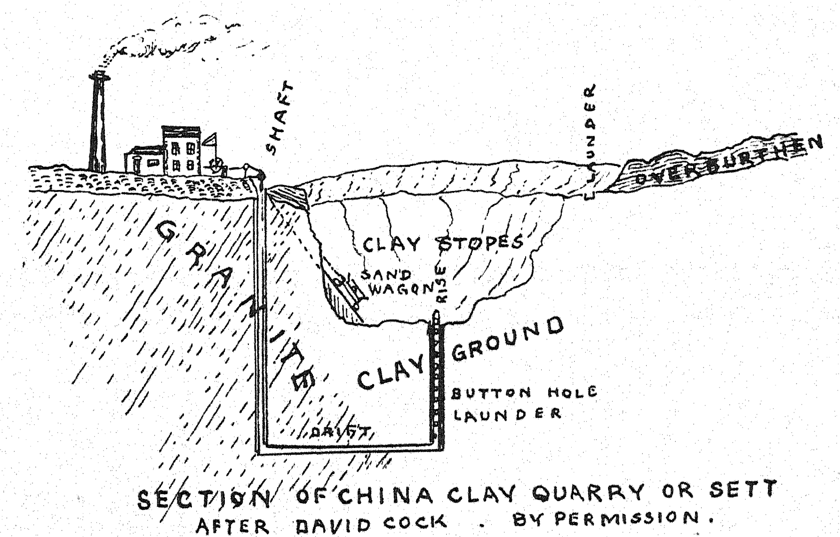
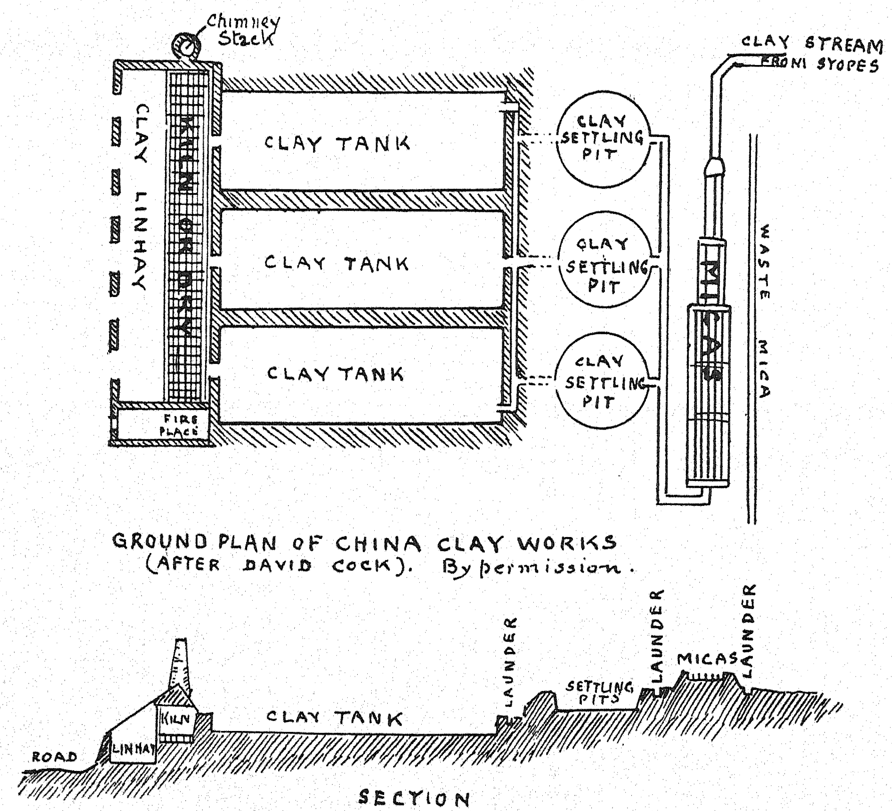


FIG. 160.—China-clay sett. (*After David Cock.*)

reduced, and its area enlarged, so as to divide the stream and permit of it passing simultaneously over several drags abreast. Distinct groups of drags are arranged in succession—the first to stop the coarsest mica, the sluices being at times assisted by sieves; while succeeding groups detain the finer particles of micaceous clay, and relatively coarse particles of the clay itself. The speed of the stream must be regulated accurately, so that only such velocity is attained as will allow of the subsidence of the several impurities on the drags assigned for their treatment. When these drags are full of accumulated deposits, the stream is either diverted to another system of drags, or temporarily stopped, while the mica and micaceous clay is cleaned out.

But to follow the clay-stream itself. On emerging from the mica-catches it is conducted into pits, often 30 feet diameter and 7 to 10 feet

deep, lined with granite or suitable walling-stone, and allowed to rest for several weeks. When the clay has subsided, the upper water is decanted by removing plugs from a frame of plugs inserted in the side of the pit. When most of the easily decantable water has run off, the cream-like clay is caused to flow into shallow tanks, 60 feet by 30 feet by 6 feet deep, where it is allowed to thicken still more until of the consistency of cream-cheese.



FIGS. 161 AND 162.—Ground-plan and elevation-section of china-clay works. (*After D. Cock. By permission of Mrs. David Cock, Liberty Hall, Roche.*)

Afterwards the clay, containing about half its weight of water, is conveyed to the drying-floors in hand-barrows, or by mechanical arrangements. The drying-floors may be either such as rely solely upon the drying action of wind and sunshine, or they may be extensive fireclay quarried floors, heated underneath by artificial heat, the latter now being almost exclusively used.

When stiff enough the clay on the drying-floors is cut across each way, so as to convert it approximately into cubical masses of 20 or 30 lbs.

weight each; and when partially dry, *i.e.*, when the clay has attained a cheese-like consistency containing about 20 per cent. of moisture, the cubical lumps are removed from the drying-floor, and stacked in large sheds called "linhays," through which wind has moderately free passage, and the drying thus finally completed by air.

China-clay is considered ready for market when it contains about 10 per cent. of sensible or hygroscopic moisture. If much overdried, or if burnt upon the drying-hearths, it may, for some purposes, be irretrievably damaged.

Modern methods effect precisely similar operations, but are at every stage assisted by mechanical contrivances, wagons, tramways, overhead hauling, pumps, machinery, etc.; and in certain cases expenses of cartage, which were formerly very considerable, are being economized by conducting the clay-stream in a liquid condition through long pipe-lines from the mines to drying-works specially erected in proximity to the seaport or railway station. The St. Neots Clay Co. are reported to be just now (1903) completing such a pipe-line of some nine miles. (See *B.C.W.*, September 1902.)

With regard to more modern methods of opening a new work, David Cock writes:—"When all the testing and other preliminary matters have turned out to be satisfactory, steps are immediately taken to work the clay on as large a scale as may be thought necessary. The method of opening the work will depend much on the position of the clay relative to the surrounding country. The chief ends to be obtained are, of course, the most economical way of obtaining and manipulating the kaolin, and the ready means of conveying it to the railway or shipping ports. If the clay discovered is in the side of a hill, much of the machinery otherwise necessary is dispensed with. In the following description of a china-clay work, however, we will suppose the discovered clay to be in a piece of low, flat ground. The extent of the clay-beds is ascertained by the 'pitting' which we have before described. As near as possible to the edge of the area, in the most convenient position, we sink a permanent perpendicular shaft through the hard granite rock, or where the rock is only partially decomposed. The size of the shaft may be assumed as 6 feet by 6 feet. . . . . From the bottom of this shaft, which we will suppose to be 30 yards deep, a horizontal drift or level is driven into the clay-ground, from 15 to 20 yards in length. From the inner extremity of this drift, a hole or 'rise' is worked up through the clay to the surface. . . . . While these operations are being prosecuted, men are employed in clearing away the overburden which rests on the clay-ground. . . . . In this manner the virgin-clay ground is exposed to view and rendered ready for working. . . . . An engine-house is built near the permanent shaft, as this is the place to which the clay will afterwards be brought from underground, and where the remainder of the machinery is fixed." (*A Treatise on China-Clay*, p. 32.)

Continuing, he explains that pumps, usually 10 or 12 inches in diameter, are fixed in the permanent shaft; and "the rise is fitted with a wooden pipe or launder, called the button-hole launder, which is about 9 inches square, and is perforated by a number of holes about 4 inches in diameter, which occur at distances of 1 foot. . . . These holes are fitted with stoppers called buttons."

The button-hole launder having been placed in position in the "rise," the space around it is filled up as closely as possible, so that all water passing from the clay-stopes to the drift, and so to the pump-shaft, shall pass through this launder.

Cock next considers that all-important feature, the "water supply," which is naturally a source of anxiety, because it is so essential to the process.

Water having been obtained of sufficient purity and quantity, it is conducted to the stopes and allowed to fall on the clay at some point higher than the button-hole of the launder then in use, and in that way clay is washed into the stream and passes along to the pump. As the working of the pit deepens, successively lower buttons are removed from the launder, until, when the bottom of the rise is reached, the button-hole launder is no longer required, but the stream runs along the bottom of the workings into the drift, and so to the pump.

The subsequent handling of the clay-stream is substantially as already described, except that mechanical contrivances are introduced to facilitate, cheapen, and improve production.

Properties.—In considering these it must be premised that we are referring to kaolin or china-clay as a finished product, washed, separated, and dried as already described; not pure kaolinite, nor indeed kaolin as the term is sometimes used by geologists. The following notes must be assumed to apply only to the material represented by what is commercially known as Cornish china-clay, and similar products from other countries.

Usual chemical symbol, $Al_2O_3,2SiO_2,2H_2O$. Chemical composition after drying off the moisture, approximately, 48·0 per cent. silica, 38·6 per cent. alumina, 10·5 per cent. combined water, together with traces of lime, iron, and alkalies. Specific gravity, 2·2 to 2·4. Loss on drying an ordinary commercial sample, from 10 to 12 per cent. Loss on calcination of an ordinary commercial sample, from 22 to 23 per cent. or more.

It should not effervesce to dilute hydrochloric acid, but is decomposable by successive treatment with boiling concentrated solutions of carbonate of soda and sulphuric acid.

China-clay reacts for alumina when moistened with solution of cobalt nitrate and subjected to blowpipe test on charcoal.

China-clay is highly refractory, leaving an intensely white residue; but its contraction, whiteness, porosity after ignition, etc., vary in different samples,

and, together with fineness, plasticity, natural colour, and physical properties, constitute the means of estimating the relative value and most appropriate uses of individual qualities.

China-clays differ in tint of whiteness very perceptibly in their humid unburnt state, and this is rendered more evident and distinctive when a lump is dipped in water, some then assuming a grey or bluish tint, others a very marked yellow tint; but these differences do not necessarily indicate what the colour will be when burnt.

Only special empirical tests by burning trial pieces in the same kiln, and under the identical conditions they are intended to be used in, will reveal the exact tint they will assume, a great difference, to the practised eye, being often noticeable in the same quality when burned at different temperatures and under different conditions. Hence it will never do for a maker of wares which are to be burned at a relatively low temperature to purchase clay by sample burned at a higher temperature, or under any other conditions whatever than those pertaining to his own particular manufacture.

China-clays also differ sensibly in unctuousness, some having a smooth soapy touch, others feeling meagre, or, as an experienced clay proprietor once observed of a meagre clay, "it feels like ashes."

China-clays, even when well washed and quite free from sand or mica, differ, too, in plasticity, and in this respect it is claimed that china-clays found in some parts of Germany are decidedly more plastic and "fat" than Cornish china-clays.

The main influence of china-clay, in a decorative-tile body—or perhaps a more correct term would be in a "*faience-fine*" body—is to modify the tint and size, to give mellowness and fineness of grain, to impart refractoriness, and sometimes to cheapen. For when sufficient china-clay is introduced into a "*faience-fine*" body, it is more easily reduced to slip state with water, dries better on the drying kiln or hearth, grinds to dust more freely and with less expenditure of power, and within certain limits presses better in the dust-tile presses.

The burnt body, or *biscuit*, is thereby rendered more or less porous, and thus receives prints of underglaze colours quickly, and can be more rapidly dipped by immersion in liquid glaze.

On the other hand, an excessive use of this material in glazed-tile bodies is detrimental, because it induces excessive porosity, tendency to crazing of the glazes, and deficiency in tensile strength, with sequelæ in the shape of readiness to absorb offensive humid emanations whenever they arise, easy destruction by frost, etc., and thus may render the glazed tile less hygienic, and soon discoloured. A few of the more fundamental reactions observed in respect of kaolin may usefully be enumerated.

(1) Albert V. Bleininger, B.Sc., found that "In the presence of clay

substance, evolution of carbon dioxide from amorphous calcium carbonate commences slightly at about 650° C.; a drop in the rate of evolution is reached at 800°, but resumed at 850°. At 1000° C. the evolution of carbon dioxide is completed. The lime begins to react with clay substance soon after the evolution of carbonic acid begins, the clay being completely decomposed at about 850° C." (*Trans. A.C.S.*, vol. v. pp. 93, 94.)

(2) Adolph E. Hottinger, of Chicago, following up the investigations of Dr. Mäckler, found that "Kaolin with magnesia gives dense bodies at comparatively low temperatures, in distinction from lime, which has but little action at the same temperature." (*Trans. A.C.S.*, vol. v. p. 130.)

(3) Professor H. Reis, Ph.D., has experimentally demonstrated that "The effect of the size of the grain on the fusibility of the clay" is perceptible. A mixture of kaolin and calcite that had been passed through 150-mesh fused at Cone 10, while a similar mixture in which the calcite passed 80-mesh, and was retained by 100-mesh, was unaffected. (*Trans. A.C.S.*, vol. v. p. 363.)

(3) Professor C. F. Binns has shown that fine grinding of flint and feldspar, when mixed into a body with clay, has a marked influence in the compactness and vitrescent character of the body, as evidenced by the ink test. (*Trans. A.C.S.*, vol. v. p. 290.)

TABLE OF CHEMICAL ANALYSES OF KAOLINS OR CHINA-CLAYS.

Material or Locality.	SiO_2.	Al_2O_3.	FeO and Fe_2O_3.	TiO.	CaO.	MgO.	Ca. Phos.	Alk.	Organic and Loss.	Combined Water.	Moisture.	Analyst or Authority.
Tong-kang (China), . .	50·50	33·70	1·80	...	...	0·80	...	1·90	...	11·20	...	Brongniart.
Sy-kang (China), . .	55·30	30·30	2·00	...	...	0·40	...	3·80	...	8·20	...	Brongniart.
Kudaru-yama (Japan), .	49·93	38·73	1·58	...	...	0·20	...	2·88	...	7·60	...	Prof. H. Wurtz.
Ômi (Japan), . . .	52·13	27·98	1·85	...	0·90	0·42	...	3·09	...	7·55	4·13	Prof. R. W. Atkinson.
Seilitz-Meissen (Saxony), .	56·49	30·75	0·48	...	0·25	0·30	...	0·96	...	10·84	...	C. Krister.
Zettlitz (Bohemia), . .	46·82	38·49	1·00	...	...	...	...	1·40	...	12·86	...	Dr. Seger.
Grünstadt (Rheinpfalz), .	53·17	33·72	0·86	...	0·07	0·22	...	0·36	...	12·03	...	Pfalzisch Ch.
" " .	47·81	38·15	0·77	...	0·21	...	...	1·26	...	11·28	..	Pfalzisch Ch.
Pilsen (Bohemia), . .	59·42	27·15	1·77	...	...	0·52	...	1·50	...	9·85	...	Dr. H. Ries.
St. Yrieix (France), . .	48·00	37·00	...	...	...	...	...	2·50	...	13·10	...	Berthier.
Coussac-Bonneval (France),	47·71	36·78	...	...	...	...	...	2·58	...	13·03	...	Dr. H. Ries.
Neuvic-sur-l'Isle (France), .	55·10	31·00	2·44	...	...	trace	...	...	...	11·20	...	Russy.
" " " .	47·80	36·90	1·70	...	...	trace	...	...	...	13·10	...	Russy.
Edgar (Florida), . .	46·11	39·55	0·35	1·20	...	0·13	...	...	...	13·78	...	Dr. H. Ries.
Dry Branch (Georgia), .	45·35	39·75	trace	...	0·25	0·18	...	0·38	...	13·68	...	T. D. Young.
Macon (Georgia), . .	43·71	40·64	0·09	...		...	...	...	...	13·38	1·60	N. P. Pratt Laby.
Dillsboro (N. Carolina), .	46·47	38·14	0·36	...	0·50	1·09	...	0·64	...	13·61	...	Harris Clay Co.
Webster (N. Carolina), .	45·70	40·61	1·39	...	0·45	0·09	...	2·82	...	12·49	...	Dr. H. Ries.
Hockessin (Delaware), .	48·40	37·62	0·52	...	...	...	...	1·22	...	12·66	...	Prof. Binns.
Mt. Holly (Pennsylvania), .	63·17	22·20	...	...	0·05	3·08	...	...	...	4·97	...	(?)
Brandywine Summit (Pa.),	46·27	36·25	1·64	...	0·19	0·32	...	2·53	...	13·53	...	Dr. H. Ries.
Cornwall (England), . .	48·26	37·64	0·46	...	0·06	trace	...	1·56	...	12·03	...	Dr. H. Ries.
" " . .	45·52	40·76		...	2·17	...	...	1·90	...	9·61	...	Lord Playfair.
" " . .	46·38	38·60		...	3·47	...	...	1·77	...	9·08	...	Lord Playfair.
Stawell (Victoria), . .	62·4	26·01	traces	...	...	...	...	0·78	...	6·90	2·10	Dept. Laby.

Cornish China-Stone.—To William Cookworthy, the discoverer of Cornish china-clay, belongs whatever honour is due to the discoverer of Cornish china-stone, of which the annual output is now nearly sixty thousand tons. He discovered it first on Tregonnin Hill, and subsequently found other deposits in the parish of St. Stephen's; and he very clearly reveals his keenness of research by the fact that he observed that the more recently found quality from St. Stephen's was more suitable for use in bodies than that of Tregonnin Hill. The writer having been over both the districts named, and having practical acquaintance with the products of each, can confirm this experience of Cookworthy's.

There are two distinct qualities of china-stone found and formerly worked near Tregonnin Hill—one having a peculiar snow-like appearance, like partly decomposed haplite, and one of a very coarse-grained yellowish-buff kind, like decomposing giant-granite, each quite easily distinguishable from the sorts quarried so extensively in the locality around St. Stephen's.

This rock was originally called by Cookworthy *moor-stone* or *growan*. The reason for this does not seem apparent, unless possibly to denote some locality of its occurrence. Geologically, its incidence is almost identical with that of Cornish china-clay, from which it differs by being in a less advanced condition of decomposition Its felspathic nature not being completely destroyed, it vitrifies when sufficiently burned, and the rock is generally still tough to break and too coherent to permit of it being washed for china-clay; indeed, it is at times used locally for building-stone. As a rule, it is found under an overburden consisting of about 1 foot of loose earth, and then from 6 to 20 feet deep of discoloured gravel and small stone, the bed of china-stone itself being from 12 feet to 16 feet thick, underlaid with a harder purple variety of china-stone, or a granite.

It is generally quarried from extensive surface openings by means of drills and explosives. Intrusive veins of schorl and of tin-stone are sometimes met with, and these, together with inferior parts of the stone itself, must be most carefully separated and removed. Only great experience and care will ensure satisfactory selection, because, to an ordinary observer, inferior stone is almost indistinguishable from the good quality.

Cornish china-stone is referred to in the *Handbook to the Collection of Pottery and Porcelain in the Museum of Practical Geology, Jermyn Street, London, 1893*, on p. 28, and the following excerpts therefrom may be serviceable:—"The china-stone of Cornwall . . . . is a disintegrated granite rock, consisting usually of a mixture of quartz, partially decomposed felspar, and scales of a greenish-yellow micaceous mineral called gilbertite. The extent to which the felspathic constituent has suffered alteration varies materially in different varieties of china-stone, but the felspar always retains more or less of its alkaline silicate, which thus renders the rock fusible. It is often associated

with fluor-spar, which materially increases its fusibility. It is generally assumed that china-stone represents the disintegrated granite rock, which, in a more advanced state of decomposition, furnishes kaolin; but the relation between the china-stone and china-clay is still somewhat obscure. The stone seems in many cases to occur as patches and bands in the granite. The china-stone is quarried chiefly from the granite of St. Stephen's, in Cornwall, which furnishes also some of the best kaolin. In quarrying the stone those parts should be avoided in which it becomes intermixed with schorl, or black tourmaline, a mineral somewhat common in the granite of which the china-stone forms a portion." (*Handbook*, p. 28.)

We learn from the same article that J. H. Collins, F.G.S., in his work on *The Hensbarrow Granite District*, *1878*, proposes the term "*Petuntzyte*" for china-stone, in distinction from the term "*Carclazyte*" for native china-clay rock; and that Mr. J. B. Hannay, of Glasgow, analyzed three samples of the St. Stephen's china-stone, with the following results:—

	I.	II.	III.
Silica,	73·39	69·50	71·66
Alumina,	16·50	17·85	18·79
Lime,	0·50	2·66	1·70
Magnesia,	0·31	0·12	0·35
Potash (with a little soda),	7·66	7·98	6·60
Iron,	trace	trace	trace
Manganese,	...	trace	trace
Fluorine,	0·74	0.71	0·14
Water,	1·25	1·30	0·91
	100·35	100·12	100·15

Preparation.—The fundamental essential is efficient selection under experienced supervision; failing this, all else is of little avail, no subsequent treatment can repair inferiority arising from bad selection.

Then, again, there are decided differences in the qualities of Cornish china-stone from different quarries; one may be preferable for one purpose, and another for another. This, of course, must remain subject to the discretion and preference of the individual buyer.

The stone, when carefully selected and dressed by axing off the stains, is in irregular-shaped lumps of from 1 lb. to 100 lbs. weight, or even occasionally rather more. It is then ready for sale to potters' millers, who make it their business to grind potters' materials. Sometimes this is done by the proprietors of the quarries, or by the proprietors of the potteries or tilework, when they have the requisite machinery.

Most generally the ordinary potter's wet-grinding flint-mill is employed (Benson's Patent—see Flint); but when the stone is required for glaze-frits or glazes that are afterwards ground, some of the dry-grinding mills present the ingredient in a very eligible condition for such purposes. But in these

cases the ground material should be frequently tested for metallic steel or iron, which may become abraded from any metallic parts exposed by the wearing away of the porcelain or wooden lining of the cylinders or crushers.

Properties.—Specific gravity, about 2·6. Loss on drying an ordinary commercial sample of dried ground Cornish china-stone, about 3 to 6 per cent. Loss on drying and calcining ground stone, 4 to 8 per cent. The native stone should not effervesce with HCl., but ground stone may do so slightly, because of the slight quantity of carbonate of lime, wearing into the material during grinding, off the mill-stones, which are or were often chert from Derbyshire limestone formations.

When burned in a Staffordshire whiteware potter's biscuit oven, the ground china-stone assumes a semi-vitreous, opaque white state; at higher temperature this becomes more and more completely fused or melted, and at the heat of the bone-china biscuit ovens it melts down out of form into a vesicular glassy mass of creamy-white colour.

Inferior qualities are recognized sometimes by their want of vitrescence, which may still be accompanied by very white colour, and sometimes by dark colour, or specky characteristics. Cornish stone is, however, decidedly less fusible than orthoclase felspar, and does not become transparent at any heats usually attained by earthenware or decorative-tile works.

It is used in small quantity in glazing tile-bodies; and in large proportion, associated with felspar, in the vitreous tile-bodies. It is also an almost constant ingredient of glazes and glaze-frits.

The chemical composition of the ground stone varies according to the source of supply, the stage of decomposition, the depth of the quarry, and the nature of the mill-stones.

A fairly reliable average chemical analysis is that of the average of seven analyses quoted by Binns in *Ceramic Technology*, namely :—

Silica,	72·77
Alumina,	17·23
Lime,	1·40
Magnesia,	0·30
Iron oxide,	0·13
Fluorine,	0·22
Alkalies,	6·49
Water,	1·64

Mr. W. Jackson, A.R.C.S., instructor in pottery to the Staffordshire County Council, observes that there is considerable difference in the composition of the undecomposed and the partly decomposed Cornish stone (the former being of a purplish-grey colour and called "blue," the latter "yellow"). He says :—"The difference of most importance between these varieties is in their alkaline contents, which may vary from about 7 per cent. in the blue to 3 per cent. in the yellow." (*Pottery Gazette*, May 1903, p. 501.)

Langenbeck carries the inquiry into the chemical composition of this ingredient a stage farther by separately calculating the three component minerals. He writes:—"Cornwall stone, a partly decomposed granite, mined in Cornwall, England, is used by English potters as their principal pottery flux, and also finds considerable application in the United States. All that is used here is imported, no material resembling it having as yet been commercially developed within our borders.

"An average sample of a good quality of this material has the following composition:—

	The Entire Material.	The Portion Insoluble in H_2SO_4 and Na_2CO_3.
	Per cent.	Per cent.
Silica,	73·57	57·69
Alumina,	16·47	4·70
Ferric oxid,	0·27	0·30
Lime,	1·17	0·10
Magnesia,	0·21	0·12
Alkalies,	5·84	3·50
Combined water,	2·45	0·00
	99·98	66·41
Combining weights of the alkalies,	44·6	38·4

RATIONAL ANALYSIS.

	Per cent.
Clay substance and mica,	33·57
Feldspar,	25·31
Quartz,	41·10

PERCENTAGE COMPOSITION OF THE

	Clay Substance and Mica.	Feldspar.
	Per cent.	Per cent.
Silica,	47·27	65·55
Alumina,	35·04	18·57
Ferric oxid,	0·00	1·18
Lime,	3·18	0·40
Magnesia,	0·26	0·47
Alkalies,	6·96	13·83
Combined water,	7·29	0·00
	100·00	100·00

"The figures show that the kaolinizing decomposition of the rock has proceeded to but a limited extent, the 'clay substance,' as in this sample, consisting in the main of mica. This is further proven by the constant presence of fluorine, which, though it has been ignored as a separate element in the above analysis, has been found present to the extent of 1·66 per cent.

"It may be justified, in the case of this material, in which mica plays

nearly as important a part as the feldspar as fluxing constituent, to give it a separate place in the rational analysis, for the better guidance of the potter.

"Cornish stone is by no means as uniform in character and composition as potters generally believe. The portion insoluble in sulfuric acid and sodium carbonate solution is in many cases markedly greater in alumina than in that of which the analysis has been given, and not infrequently the silica is either largely soluble in the sodium carbonate solution, or is more readily made so by the action of the sulfuric acid than quartz commonly is.

"A sample showing both of these peculiarities analysed as follows:—

	The Entire Material.	The Portion Insoluble in H_2SO_4 and Na_2CO_3.
	Per cent.	Per cent.
Silica,	72·99	42·72
Alumina,	17·58	7·83
Ferric oxid,	0·15	0·10
Lime,	1·25	0·71
Magnesia,	0·37	0·19
Alkalies,	6·20	4·31
Combined water,	1·77	0·00
	100·31	55·86

RATIONAL ANALYSIS.

	Per cent.
Clay substance, mica, and soluble silica,	44·45
Feldspar,	40·68
Quartz,	15·18
	100·31

PERCENTAGE COMPOSITION OF THE

	Clay Substance, etc.	Feldspar.
	Per cent.	Per cent.
Silica,	68·10	67·68
Alumina,	21·94	19·24
Ferric oxid,	0·11	0·25
Lime,	1·21	1·75
Magnesia,	0·41	0·47
Alkalies,	4·25	10·61
Combined water,	3·98	0·00

"The sum of the alkali and combined water in this 'clay substance' falls far short of what would be demanded by a mixture of mica and pure clay; while on subtracting the excess of silica, assuming it as uncombined, but soluble in sodium carbonate solution, and recalculating the residue on a percentage basis, they assume the proper proportion. . . .

"But more important than the difference in character of the contained minerals, or a variation in the apportionment of the elements to the different

mineral groups, is the variation in ultimate chemical composition of Cornish stone, particularly in the proportion of alkalies, as in the following :—

	Per cent.	Per cent.
Silica,	74·55	73·77
Alumina,	17·37	16·05
Ferric oxid,	0·26	0·23
Lime,	1·68	1·14
Magnesia,	0·54	0·22
Alkalies,	3·68	7·52
Combined water,	2·04	1·78
	100·12	100·71

(*Chemistry of Pottery*, 110–114, Chemical Publishing Co., Easton, Pa.)

For commercial reasons it is sometimes desirable to prepare substitutes for Cornish china-stone. The readiest way of calculating this, so as to enable a mixture of flint, felspar, and kaolin to be used instead, is by accepting Professor Binns' method (see p. 25, *Ceramic Technology*), where he points out that Cornish china-stone may be considered approximately one equivalent of alkali, two of alumina, and eighteen of silica. If, therefore, we take—

1 eq. felspar (= 1 eq. alkali, 1 eq. Al_2O_3, 6 eq. SiO_2),
1 eq. kaolin (= —— , 1 eq. Al_2O_3, 2 eq. SiO_2),
10 eq. flint (= —— , —— , 10 eq. SiO_2),

that will yield the desired composition.

Converting these figures, we get—

10 eq. flint = 10 × 60 = 600 flint = 42·43 per cent.
1 eq. kaolin = 1 × 258 = 258 kaolin = 18·24 ,,
1 eq. felspar = 1 × 556 = 556 felspar = 39·32 ,,

This, however, upon comparison with the average of six analyses of china-stone (see p. 33, *Researches on Leadless Glaze*), seems to give too high a proportion of silica. A mixture as under would appear to be more in accordance with average analyses, perhaps:—

Flint,	40	per cent.
Kaolin,	19	,,
Felspar,	41	,,
	100	

Jersey China-Stone.—This is a harder and somewhat finer-grained rock than most of the Cornish china-stones, and is much less kaolinized. It is rather like the *purple* Cornish china-stone, though of finer grain, and also, to some extent, approximates Meldon granulite and Tregonin Hill stone.

Apparently it consists almost entirely of finely grained quartz and felspar; mica being conspicuously absent, but here and there a careful examination under the magnifying glass may reveal specks of what seems to

be pyrites, although the analysts have not mentioned sulphur in their certificates. It therefore answers fairly well to the description of the rock called by mineralogists haplite or granulite.

Jersey china-stone is of comparatively recent introduction to the ceramic industry, the rock having been discovered about the year 1866 A.D., in the parish of St. Laurence, Jersey, by the late Mr. Henry Vatcher. At that time an association, called the Cornwall China-Stone Company, were maintaining prices for Cornish china-stone at 24s. and 22s. per ton at Cornish ports. Jersey china-stone was put on the market at 11s. per ton, and made its way so well that in a few years the Cornish association disbanded, and the price of Cornish stone fell to 14s. per ton or less. That occurred late in the year 1874. In

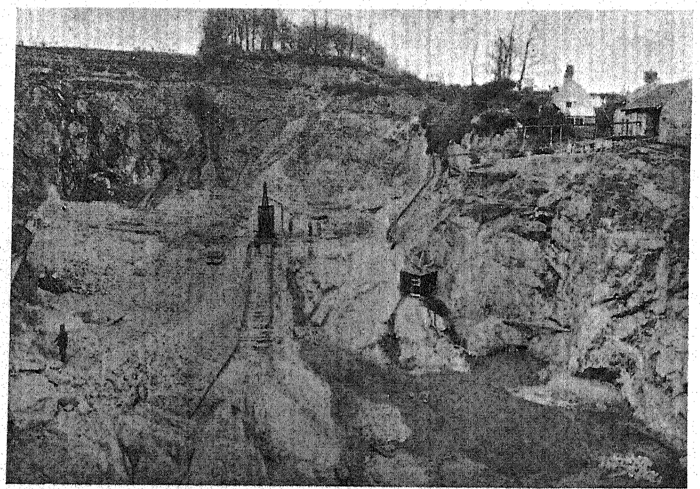


FIG. 163.—Rosemount china-stone quarry, Jersey, 1903.

a circular issued on 10th July 1877, Mr. Vatcher complained bitterly of misrepresentation and enmity on the part of his Cornish competitors; and claimed that during the two and a half years then terminating he had been the means of reducing the cost of china-stone to millers at the rate of £40 to £50 on every hundred tons consumed, which, he said, was equivalent to about £50,000 during the two and a half years. As a matter of fact, however, the millers gained little by the change—some, indeed, lost heavily, having large stocks bought at the old prices; for when china-stone was reduced, the millers, in competition with each other, immediately reduced the price for ground Cornish stone, and those who had large stocks lost the difference.

Jersey china-stone in its native state, when properly selected, possesses a steel-grey or silver-grey colour, with occasional slight brownish-yellow streaks; a granular but rather compact texture, not particularly translucent

in the lump, and so much resembling some common road macadam as to cause hesitation in its use. It is only upon proof by burning and testing in actual practice that fears are completely dispelled. When burned in a potter's kiln at a high temperature, properly selected and properly trimmed, Jersey china-stone becomes white, translucent, and vitrescent, according to the heat to which it has been subjected ; often more translucent than Cornish china-stone after burning, because of the lower degree of kaolinization. It is naturally hard to crush and to grind, but when incipiently calcined it becomes more amenable to grinding.

Preparation.—After having been blasted from the quarry by means of gunpowder and dynamite, the stone is selected and trimmed, and then is crushed by powerful steel crushing-mills, erected at the quarries. It is mostly shipped in this crushed state to potters' millers, and by them ground either alone or as a compound with Cornish china-stone. Like felspar, Jersey stone has a tendency to "set" on the grinding-pans, and for that reason some admixture with Cornish stone is preferred by the miller. On the other hand, the tendency of Jersey stone to settle, and its weaker affinity for water, enable a heavier pint weight of slop-ground china-stone to be obtained by its means than by ordinary Cornish china-stone. In comparison, however, with blue or purple Cornish stone this tendency is less marked.

Jersey china-stone is not infrequently specified for use in certain cases for glazes, because it is supposed to fuse more easily than Cornish.

Properties.—The chemical composition is shown by the following analyses, very recently made from a carefully averaged specimen of Jersey china-stone, taken direct from the stocks of stone at the quarry by the present proprietress.

	Wm. Foulkes Lowe, F.I.C., etc., Assay Office, Chester.	Hugh Hughes, Connah's Quay.
Silica,	78·15	78·180
Alumina,	13·46	14·820
Iron oxide,	0·38	0·080
Lime,	0·55	0·330
Magnesia,	0·18	0·100
Potash,	3·74	} 5·780
Soda,	3·80	
Fluorine,	...	0·016
Water of hydration,	...	0·640
	100·26	99·946

It does not follow, however, that Jersey china-stone differs to that extent in alkaline contents, for both analyses were made from the same most carefully averaged crushed sample.

Upon comparing these analyses with those of Cornish china-stones, the most noticeable differences are a larger percentage of silica and a lower

percentage of alumina in the Jersey stone. Comparison with pegmatite of Haute Vienne (France) shows a similar difference, but of smaller degree—that is to say, Jersey china-stone approximates more nearly to French pegmatite than Cornish china-stone; the same approximation being noticeable when the analysis is compared with Limoges glaze analysis. (See Seger's *Collected Writings*, p. 553.)

Experts may also immediately note a much lower percentage of calcium oxide than is usually found in commercial samples of ground china-stone, in which a percentage of from 1·95 to 4·20 of CaO is found. This may be explained by the fact that in averaging the Jersey stone sample, and preparing it for analysis, exceptional care was exercised to avoid the least contamination. Hence, possibly if Jersey china-stone were ground upon an ordinary potter's mill-pan by the wet method between chert runners and pavers, lime, abraded from the grinding-stones, might then show in analysis. Possibly, too, if proper precautions were exercised in preparing samples of Cornish china-stone for analysis prior to placing them in the hands of the chemist, Cornish china-stone might then appear to yield a lower percentage of lime.

Felspar or Feldspar.—The felspars are a group of crystalline minerals, often of lamellar form, composed of silica and alumina chemically associated with alkalies and alkaline earths. The bases frequently replace each other, and thus, in conjunction with physical causes, numerous varieties result.

The colour of felspars in their native state is sometimes almost white, and sometimes pale grey, drab, or light red; always more or less translucent and lustrous. The streak or powder is white or greyish-white. Cleavage is particularly well developed in some kinds, the broken pieces often exposing definite rectilinear planes.

Felspars are very widely distributed in the form of crystals commingled with quartz, mica, and hornblende, together constituting rocks such as granite, gneiss, syenite, granulite, haplite, quartz-porphyry, felspar-porphyry, and the like.

Obsidian, pitchstone, and certain lava products also contain felspathic substance in an amorphous or vitreous condition.

Less frequently, perhaps, felspars occur in isolated masses or dykes in Plutonic rocks, in a condition of comparative purity; when so found, they become of great service to ceramic art.

The varieties preferred by ceramists are the potash and soda felspars, orthoclase, microcline, oligoclase, and albite.

These may be briefly described as follows:—

Orthoclase: a potash-felspar, the crystals of which dispose themselves in lamels or flakes of the monoclinic system, so as to be easily cleavable into thin flat plates, the planes of which are lustrous. The colour is usually either translucent light red, translucent drab, or translucent creamy-white. The

surface can just be scratched with the point of a sharp knife. Sp. gr., 2·39 to 2·62 (Rutley).

Microcline: a potash-felspar, differing from orthoclase only in microscopic structure; and, according to Rutley, having a greenish-blue play of colour. The light-red or pink felspar of Bedford Township, near Kingston, Ontario, Canada, is said to be microcline.

Oligoclase: a felspar in which soda is usually the predominant alkali, but by some considered to be a mixture of albite with orthoclase; of somewhat imperfect cleavage; crystallizing in the triclinic system; colour, greyish, greenish, or slightly yellow. Sp. gr., 2·58 to 2·7 (Rutley). Said to fuse more readily than either orthoclase or albite. Occurs near Stockholm (Sweden) and Arendal (Norway).

Albite: a soda-felspar, triclinic; may be massive, granular, or lamellar; the cleavage faces generally having a pearly lustre. Colour, white or only slightly tinted. Hardness, 6–7. Sp. gr., 2·59 to 2·65 (Rutley).

Lime-felspars, such as labradorite, although constituting rock-masses of considerable extent, are not much used by ceramists. Why this should be in cases where gypsum is used as an ingredient in bodies and glazes is not quite clear. But the greater resistance to decomposition offered by potash-felspar probably accounts for its preference for porcelain, particularly for the glazes.

Several composite rocks, containing quartz-crystals associated with crystals of felspars, when found of requisite purity and in sufficient abundance, are also extensively used in the porcelain industry. The following are the most common of these:—

Quartzose-felspar, in which the two constituents are quite plainly distinct, the one in colourless angular crystals, the other usually light red, more or less lamellar. Found in quarries near Stockholm (Sweden), Arendal (Norway), and Verona (Canada); possibly also as vein-stuff in many other felspar formations.

Haplite or *Aplite*, a granular crystalline rock composed of felspar and quartz, referred to by F. W. Rudler, F.G.S., as micaless granite, appears to be commercially represented by Tregonnin Hill stone, Jersey china-stone, and Meldon granulite.

Pegmatite or *Cailloux:* a semi-kaolinized porphyritic variety of haplite, in which the felspar often has a yellowish colour; this occurs in the granite hills of Limousin (France), and is largely used in ceramic works at Limoges. Brongniart states that it is felspar and quartz, with sometimes a little mica and talc. Cornish china-stone is also not infrequently called pegmatite.

Quartz-felsite or *Quartz-porphyry* finds a useful industrial representative in the "elvan," "growan-stone," or "china-stone" of Cornwall, although this is often in a partially kaolinized condition. It is in this latter form very extensively used by manufacturers of white earthenware and bone chinaware.

Petuntze, or Pe-tun-tse (white-paste-bricks) of the Chinese, proved to be a rock of kindred nature to the foregoing, which has been levigated or in some way prepared and formed into brick-shaped pieces.

Commercial Sources of Potters' Felspars.—A very considerable portion of the purest felspar used in Europe for the manufacture of hard-porcelain and other wares is obtained from Sweden and Norway, the total Scandinavian output being about thirty thousand tons per annum, of which rather over half is of Swedish origin.

Mr. Robert Almström, of Rörstrands, Stockholm, has very kindly supplied the following particulars:—The principal quarries in Sweden are Ytterby, Svinninge, and Magretslund in the neighbourhood of Stockholm; Lunden and Tölläs on the Swedish west coast; Bro-Kolswa, Sala, in the middle part of the country; and several other places where smaller quantities are raised. The oldest and most renowned quarry is that of Ytterby, which has been worked more than a century, and where the rare minerals gadolinite, fergusonite, yttrotantal have been found. In these minerals the new chemical elements yttrium, erbium, ytterbium, skandium, etc., were discovered.

Ytterby, Svinninge, and Sala belong to the Rörstrands Limited Company. The output from these quarries was in 1890 about three thousand eight hundred tons. The output from Bro is three thousand six hundred tons, and from Magretslund two thousand tons.

In Norway the quarries are situated chiefly in the neighbourhood of the towns Arendal and Christiansand, on the south coast of the country; both towns are on the west of the Christiania Fjord.

Messrs. H. Flemming & Co., of Stettin (Germany), writing in July 1903, say that felspar is still found at Aue (Saxony), but only sporadically, and the quarrying of it does not leave a margin of profit, and therefore does not take place.

In *Bohemia* there are some large deposits of felspar, and also in *Bavaria*, in the neighbourhood of *Wunsiedel*; but all these Bohemian and Bavarian felspars are, as regards purity, much behind the Scandinavian felspars, which are now principally used in the pottery works (of Germany). The import is yearly about thirteen thousand to fifteen thousand tons of Scandinavian felspar.

Brongniart quotes analyses of felspars from Russia, Finland, France, Bavaria, Saxony, the Pyrenees, and America. And C. F. Binns, in *Ceramic Technology*, gives analyses of felspars from Germany, Scotland, France, and Spain. Thus it appears that when judiciously sought the commercial sources of felspar are comparatively numerous and widely dispersed.

Brongniart, if we understand him correctly, stated that "The felspars used in porcelain are never pure. They are rocks of mixed minerals belonging to the species called pegmatite, and which are essentially com-

posed of felspar and quartz in distinct particles." This in a great measure correctly applies to the use of felspar at Limoges and Sèvres, and originally in Germany too; also to the English use of Cornish china-stone; but scarcely applies to some of the very pure felspars now obtainable from Sweden and Canada.

For some time, Brongniart tells us, the pegmatite or quartzose-felspar of St. Yrieix was not distinguished from the surrounding granite, because of its variegated irregular appearance and porphyritic or granitic character; but that since A.D. 1780 this local *cailloux* or pegmatite has been used by itself for the glazes almost exclusively, and mixed with kaolin, etc., for the bodies of Limoges porcelain. On p. 272, vol. ii., he gives five analyses of this at different periods, which we repeat in the list of analyses at end of this paragraph.

In America veins of felspar are worked in the States of New York, Pennsylvania, Maryland, Connecticut, and Maine; the total production during 1901 amounting to 34,741 tons, of which 71·3 per cent. was ground by the producers.

Judging by small specimens and copies of analyses, it seems that Maine felspar is usually a yellowish-white, slightly micaceous potash-felspar; that of New York State a somewhat dull, compact white variety with mica scales here and there; that of Pomeroy (Pa.) a yellowish translucent sort like Limoges felspar.

Within the last few months a felspar formation has been found at Jonca, a few miles west of the Mississippi River, near St. Genevieve, about sixty miles south of St. Louis (Mo.). Several large veins, 10 to 15 feet wide, are reported; and as a new railway runs near by, the prospects of development are favourable.

But the supply of felspar for American ceramists has been most influentially augmented by the discovery of felspar-bearing rocks in Canada. These, according to the *Mineral Statistics Report*, kindly supplied by Dr. Robert Bell, Director of the Geological Survey, are mostly found in the provinces of Quebec and Ontario. It is stated that the crystals of felspar are found in veins or masses of pegmatite all through the Laurentian rocks of Canada.

From Hull Township, Wright County, Quebec, and from Carleton County, Lanark County, and Frontenac County, Ontario, large quantities of felspar are said to be shipped to the United States, the output increasing from about fourteen hundred tons in 1897 to over seven thousand tons in 1902.

The most energetic and successful development is said to be that of the Kingston Felspar Mining Co., at mines in Bedford Township, Frontenac County, Ontario. The mines are situated within about two miles of Glendower Station on the Kingston and Pembroke Railroad.

The proximity to Kingston, on the north-west coast of Lake Ontario, with the United States just across the lake, and the great pottery and tile making districts of New Jersey, Ohio, Indiana, and Pennsylvania all within favourable commercial range, is very fortunate, and this apparently is being taken advantage of.

Analysis and inspection indicate good quality, and—what is far more to the point, practically—extensive use confirms its superiority.

Messrs. James Richardson & Sons, of Kingston (Ont.), writing on the 1st June 1903, inform me that all previous figures are now being greatly exceeded. They say:—"The quantity of feldspar that we are shipping to the United States this year is sixteen thousand five hundred tons, and there is probably three thousand five hundred going from other people, making a total of about twenty thousand."

This felspar is rich light-red colour, remarkably well formed, with well-developed cleavage, lustrous, translucent, and is pronounced to be microcline; that is, a variety of orthoclase with peculiar microscopical structure. For analyses, see list.

In the *Report of the Ontario Bureau of Mines for 1903*, kindly sent by T. W. Gibson, Esq., Director, these feldspar mines are referred to in detail seriatim. Of the Richardson Feldspar Mine it is stated that "With the exception of four months in the spring, when all operations were suspended, last year witnessed a fairly heavy production, which frequently went as high as two hundred tons of feldspar per day. . . . The mine-workings or quarries are confined to an area of about 150 feet by 200 feet, all of which, with the exception of a small central portion, has been stripped of several feet of clay-covering to allow of raising rock from every available point. The main working extends as an open-cut from end to end of the west side, 175 feet long by 50 feet wide by 35 feet deep at the west face, the floor rising in three benches of 5 feet each from the south end. The pit next in size lies at the east side, 50 feet long by 50 feet wide by 20 feet deep. . . . Numerous other working-places are scattered at various points.

"Feldspar covers the floor of this whole mine-area, practically all of it clean and pure; but on the west side, in the wall of the main cut, the good spar runs flatly under a capping of granite, which, on account of the rising surface of the hill, has gradually increased in thickness to 12 feet at this distance in. This capping has had to be blasted off first and removed separately, to avoid contaminating the feldspar beneath. On the floors of the workings any cobbing and sorting that may be necessary are carried out, so that the clean spar may not be again handled on the surface. . . . The power-plant includes a 30-h.p. locomotive-type boiler, and a double-drum duplex-cylinder hoist-engine."

In the same report the mines of the Pennsylvania Feldspar Co. are mentioned. These are also situated in Frontenac County, and, though the properties were only leased last year but one, they have, since the month of November 1902, produced several thousands of tons of spar, which has been immediately shipped away to the company's works in the United States.

Mr. W. E. H. Carter, who inspected these and other mines in Eastern Ontario, on behalf of the Bureau of Mines, states that the Border Mine is situated in Portland Township, near the south shore of Long Lake, about two miles from Verona, on the K. & P. Railway. The mining work is confined to one open pit or quarry, 40 feet long by 30 feet wide by 6 to 12 feet deep. The band of feldspar runs in a north-easterly to south-westerly direction through a formation of gneiss. It is said to be traceable for about 1000 feet in length, with a width at the pit of 40 feet. The feldspar is pink microcline with cleavage planes well developed, one of which lies flat and gives the whole a bedded appearance. Intermixed are occasional stringers of clear quartz, together with some plagioclase feldspar near the gneiss and black mica schist walls. The blasts shatter the spar into small material, this allowing of fairly close and rapid hand-sorting. The Freeman Mine of the same company is partly in Portland Township and partly in Loughborough Township, on Fourteen Island Lake, about five miles east from Verona. Mining here has been confined to one open-cut or quarry, 10 feet by 40 feet in plan by 30 feet deep at the face, following into a band of white feldspar, which is said to cut through a hill over a traceable length of 500 feet. The feldspar contains a rather large quantity of quartz in small disseminated stringers, and also some black mica. . . . . Its use is said to give equal satisfaction to that of the pink variety.

Of the Walker Mine, in Portland Township, five miles north-east of Hartington, or the same east of Verona, two pits or quarries were opened out, each about 20 feet by 20 feet in plan by 20 feet deep at the face in the hill. The feldspar here is also white, but more glassy than at the Freeman Mine, on account of better-defined planes of cleavage.

Of the Harris Feldspar Mine (owned by Chas. Jenkins, of Petrolea) the report states :—This is located in Bedford Township, Frontenac County, four miles by road east of Bedford Station on the K. & P. Ry., and comprises an area of about two hundred acres. The mine-workings are on the top of a high hill at the north-east end of Thirteen Island Lake. The feldspar is quite similar to that of the Richardson Mine, as far as revealed in the two pits, which are the only uncovered places. It is a pink microcline with well-defined cleavage planes, and traverses a formation of grey to pink gneiss. But very little quartz or rock-matter is to be found, giving a feldspar of first-class quality.

Preparation.—The most essential preliminary is scrupulously careful selection at the quarry, so as to eliminate all inferior parts; for no subsequent treatment can appreciably improve bad or badly selected felspar.

Langenbeck says:—"Often the quartz-veins of a spar-bed may be difficult to remove, or the workmen are careless in picking over the mineral, causing more or less variation of the commercial product, against which the customer must be on his guard. Again, it may occur that the more quartzose portion of a soda-lime spar are ground separately and sold as hard or potash spar, as was the case with a lot of which the following is an analysis:—Silica, 68·82; alumina, 19·75; ferric oxide, 0·16; lime, 1·64; magnesia, 0·17; alkalies, 9·15. It is of about the same fusibility as the true potash-spar." (*Chemistry of Pottery*, p. 109, Chem. Pub. Co., Easton, Pa.)

The selected felspar is separated into different grades, namely, first quality, second quality, and quartzose-felspar, and other special designations. After arriving at the mill, felspar should be inspected and sampled, and small portions from various parts tested by burning, prior to allowing any large lot to be ground. Also, the fine "smalls" should be perfectly well sieved out and discarded, and the remaining lumps washed in grided barrows. It may then be ground on ordinary potters' mills, special precautions being taken to guard against accidents arising from the tendency of felspar, when in a half-ground condition in wet-grinding mills, to set on the mill-pan. Sometimes certain proportions of Cornish china-stone or china-clay are added to minimize the risks to the machinery during grinding. And sometimes, for various reasons, the felspar may be calcined before grinding.

When used as a component of a body, it should be ground with some little suitable addition, by the wet method, like slop flint, and washed and prepared in that manner; but for use in frits or enamels or glazes, it may be ground by any of the dry-grinding mills where it is found possible to do so, without fear of contamination by iron or steel.

Mr. Robert Almström kindly explains their method as follows:—"We assort the feldspar in three classes, first, second, and third, the third containing some small quantities of quartz.

"We prepare the feldspar in the following way:—Crush it, without previous calcining, with edge-runners, and pass it through a metal or steel sieve with about forty-two holes on the square inch.

"Then grind it wet in Alsing cylinders, lined with oak (not stoneware bricks), using small boulders or flint pebbles in the cylinders. The feldspar will, when the mill is not in rotation, settle to the walls (sides), and will cause breakage of stoneware bricks, if not removed with great caution.

"It is rather risky to grind feldspar on the common wet mills, because it

settles very strongly to the bottom of the pan, and can, if not broken up before the mill is put in movement, cause breakage of the machinery. If you cannot avoid grinding in this way, it is advisable to add some 10 to 25 per cent. of flint or china-clay or china-stone to the feldspar to prevent it settling.

"Then wash the fine-ground parts from the coarser particles.

"If you calcine the feldspar (that is, before grinding), great care must be taken that the temperature does not exceed 1200° Centigrade, the point when it commences to be fusible. If you go too far, the lumps will melt together and form an intractable mass. If calcined at about 1100° C., the cohesion of the structure will be broken and the lumps dissolved (disintegrated) into thin lamels, that can be ground without preliminary crushing. The loss in calcination must be calculated 4 to 5 per cent."

Properties.—Sp. gr., 2·4 to 2·6. Chemical symbol, $(KNa)_2O,Al_2O_3,6SiO_2$; or $K_2O,Al_2O_3,6SiO_2$.

Felspars are fusible minerals, within the range of heat employed in the ceramic art; the melting or fusing point of felspar is said to correspond with that of Seger Cone 9; and as we have already seen that Mr. Robert Almström places the temperature of commencement of fusion of felspar at 1200° C., while that of Seger Cone 9 is variously placed at 1310° C. to 1380 C., some differences in observations apparently exist. Again, different felspars may melt at different temperatures; for instance, Rutley states that oligoclase fuses more readily than orthoclase.

The best qualities of felspar melt into an almost transparent glass-like mass, free from any indication of colour, at the heat of an English china biscuit oven, which, by Watkin's table, is equivalent to from 1190° C. to 1390° C. Any tendency toward opacity or colour, or any want of vitrescence in a properly burnt trial, should be regarded as inferiority.

Mr. Almström kindly explains that "The fusibility of feldspar seems to depend not only on the greater or lesser quantity of potash or soda it contains. There are feldspars that contain a smaller per cent. of these matters, and still melt at a somewhat lower temperature; for instance, the soda-feldspar. Feldspar seldom will melt to a quite transparent glass. It generally becomes milky, sometimes with streams of colourless transparent glass. The opality does not influence upon the quality of it."

By reason of its comparative insolubility in water under ordinary conditions, it forms a manageable source of alkali in any compositions where silica and alumina are also admissible. But Daubree has shown that long-continued grinding of felspar in distilled water will bring about partial decomposition with the formation of clay and an alkaline silicate; and this is supposed to account for its tendency to sett on pan during wet grinding. (See *Trans. A.C.S.*, vol. v. p. 292.)

Some interesting experimental results with felspar are recorded in *Trans. A.C.S.*, vol. v. pp. 159, 285.

ANALYSES OF FELSPARS AND PEGMATITES.

Locality, etc.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	CO_2.	Combined H_2O.	Moisture.	Analyst or Authority.
Orthoclase or potash-felspar, . . .	64·2	18·4	...	...	...	16·75	...	...	...	...	
Albite or soda-felspar,	68·6	19·6	...	...	...	...	11·8	...	...	...	
Oligoclase or soda-lime felspar, . .	63·7	23·9	...	2·0	...	1·20	8·1	...	...	...	Geikie.
Ytterby (Sweden) orthoclase, . .	64·57	19·73	0·20	0·18	...	12·25	3·06	...	...	...	Almström.
Svinninge (Sweden) orthoclase, . .	64·40	19·30	0·30	0·40	...	12·55	2·58	...	...	...	Almström.
Sala (Sweden) orthoclase, . . .	65·30	19·71	0·64	0·68	0·18	8·81	7·32	...	...	...	Almström.
Ytterby oligoclase, .	63·00	23·0	0·30	2·62	0·03	0·38	10·82	...	...	...	Almström.
Limoges pegmatite, 1826,	73·0	16·21	...	...	...	8·4	...	...	0·6	...	Berthier.
,, ,, 1839,	74·0	18·6	...	0·4	0·3	6·6	...	...	...	...	Laurent.
,, ,, 1839,	73·4	15·7	...	1·9	0·3	7·4	...	...	1·4	...	Malaguti.
,, ,, 1841,	74·6	16·0	...	1·2	...	8·1	...	...	...	...	Marignac.
,, ,, 1842,	74·3	18·3	...	0·4	0·2	6·5	...	...	0·3	...	Salvétat.
Chanteloube (France) orthoclase, . .	64·00	20·56	...	0·38	...	14·99	...	...	...	...	Malaguti.
Chanteloube (France) albite, . . .	67·63	20·48	...	0·65	...	...	10·26	...	...	...	Malaguti.
Scottish felspar, .	65·40	19·04	trace	0·22	...	11·26	3·63	...	0·20	...	C. F. Binns.
Maine, . . .	68·30	18·69	...	...	...	12·34	0·80	...	...	...	
Litchfield (Maine), .	65·14	18·19	0·25	0·33	0·16	14·14	1·68	...	...	...	U.S.G.S.
New York State, .	65·95	19·84	...	...	...	10·30	3·20	...	...	...	
Pomeroy (Pa.), .	70·10	16·5	...	...	0·37	10·48	1·11	...	...	...	
Jonca (Missouri), .	64·8	18·0		0·6		15·9			0·7	...	
Canadian microcline, Kingston, . .	65·40	18·80	trace	none	none	13·90	1·95	0·60		...	Dr. H. Reis.
Canadian microcline, Kingston, . .	66·23	18·77	trace	0·31	none	12·09	3·11	...	...	...	Cochran.
Canadian albite, Villeneuve, . .	63·96	18·4	trace	...	trace	16·88		...	...	...	Min. Stat.

Quartz, Silica, Silver-Sand.—According to Sir Henry Roscoe, silicon, next after oxygen, is the most abundant element known. But it does not occur in a free state; it is almost always combined with oxygen in the form of silica.

One of the commonest natural forms of silica is quartz. This, when sufficiently pure, may assume a transparent colourless condition, and is then known as rock-crystal or crystal quartz. More frequently, however, it is either slightly opaline or tinted. Rose quartz, amethyst, aventurine, and cairngorm are all comparatively pure forms of silica; but when quartz is in

large masses it is often impregnated with mica, and sometimes with appreciable quantities of gold, the yellow particles being sometimes plainly visible to the naked eye.

Superior qualities of crystal quartz for high-class ceramic purposes in Europe are principally obtained from Norway and Sweden, where quartz is largely quarried for use in local iron furnaces. Quartz of a somewhat less degree of purity is found on the Malew Reef in Isle of Man; also in parts of France.

Enormous deposits of granular quartz constitute the gritstone and gannister rocks and the beds of loose silver-sand. Immense quantities of such sand, from numerous localities in Belgium and Germany, find their centre for exportation at Antwerp. And Kamenz and Hohenbocka (Saxony) are well known for their excellent quartz-sand.

The beautiful quartz-sands of Fontainebleau, whence is obtained even the bulk of that used at Whitefriars Glass Works, London, is quite historic now; but many other localities in France, such as Bonnevault, Nemours, Rouen, Montebras, Nogent l'Artand, Montereau, and Etampes, yield good sands.

In Italy the quartz-sand on the shores of Murano, near Venice, from which the famous Venetian glass is made, is especially retained for glassmakers' use, its use for other purposes, or its exportation, being legally prohibited. (*Jour. Soc. Arts*, 7th June 1886, p. 631.)

In England such sands exist at Lynn (Norfolk), Leighton-Buzzard (Beds.), Mayfield (Sussex), and in the Isle of Wight; while Staffordshire and Derbyshire furnish useful gritstones, crushable into sand; such as those of Wetley Moor, Stockton Brook, Brownedge, Biddulph, Mow Cop, and Normacott, and amongst the limestone pockets of the Weaver Hills and Wirksworth.

North and South Wales, Yorkshire, and Stirlingshire also yield serviceable quartz-sands; and it has been asserted that excellent quality of glassmakers' sand exists at Gweedore. (*Jour. Soc. Arts*, 7.6.89, p. 631.)

Looking somewhat further afield, it is stated in the *Story of Extinct Civilizations* (Newnes), p. 89, that Sidon, as of old, is still capable of supplying excellent sand for glassmaking. And John Ward, Esq., F.S.A., of Belfast, writes that in the Sûdan "there are mountains full of great veins of quartz. . . . . They run across the strata for miles, white as snow."

For the preparation of specially excellent enamels Hermann recommends the use of *infusorial earth*, which is supposed to consist of the siliceous envelopes of diatoms, and, though almost pure silica, is easily rubbed by the fingers into an impalpable powder. It is found in Germany and known as *Kieselguhr*.

In the United States of America quartz is raised in Connecticut and Maryland mostly; but, in addition, remarkably pure silica-sands, showing, on analysis, 99·5 per cent. silica, are found both in Pennsylvania and Illinois.

The latter is mined at Chicago Heights (Ill.), about twenty-seven miles from Chicago, and ground between French burr-stones by the Irwin Clay and Sand Co.

Quartz-sand from Millington (Ill.) is also said to be ground for use in pottery bodies at East Liverpool, Ohio.

Langenbeck mentions quartz-sand of high degree of purity mined in La Salle County, Illinois, and used for pottery purposes; also highly siliceous clay along Cumberland River, Tennessee. (*Chemistry of Pottery*, pp. 105–106.)

The sand washed out of Florida kaolin also proves to be particularly pure and beautiful quartz-sand; and, no doubt, there are many other sources of pure silica in the States, otherwise the immense glassworks could hardly be economically operated. The felspar quarries of Canada also yield superior quartz-rock.

Unfortunately, among suppliers of potters' requirements in the States, and still more unfortunately in the Government Reports of Mineral Resources, a misleading nomenclature is coming into use, namely, that of using the terms "*flint*" and "*quartz*" as synonymous; for example, on p. 939 of *Mineral Resources, 1901*, "*flint*" is used as a heading for statistics of *quartz*; and in trade, ground quartz is called ground rock-*flint*; and ground silica-sand is called ground sand-*flint*. This necessitates qualification when we want to speak of flints from chalk-pits, or rolled flints, and is, in the writer's opinion, an unnecessary and misleading confusion of terms.

Preparation.—With regard to quartz, preparation necessarily varies according to the purpose for which it is to be used. Hermann advises that for the finest white and coloured enamels the most colourless quartz should be selected; this, he states, is preferable to any attempts at dissolving out impurities by acid solutions. For less important purposes select quartz that does not become reddish after ignition and cooling.

As to pulverizing, Hermann writes:—"In the case of a mineral of the seventh degree of hardness, such as quartz, the comminution of large quantities would require the exertion of truly gigantic power. In order to obtain disintegration by the employment of very little force, the material is first subjected to heat followed by rapid cooling." That is to say, the quartz is heated to redness and then immediately thrown into water. "This process . . . . is known in practice as quenching. If quenched quartz be struck with a hammer, it will break into small fragments, which can easily become converted into a fine powder." (*Painting on Glass and Porcelain*, p. 87, Scott, Greenwood, & Co.)

Very large quantities of Norwegian and Swedish crystal quartz are ground by North German millers in several degrees of fineness.

The preparation of quartz-sand depends not only upon the purpose for which it is to be used, but also upon the nature of the sand itself.

Muspratt describes the purification of glassmakers' sand as follows:—"The sand, being always more or less impure when brought to the glass-works, is conveyed to an upper room, and thrown into a trough of water, where it is carefully washed. It is then placed in a trough over an oven, and, when partially dried, passes through holes into the oven. When quite dry it leaves the oven in the state of fine, glittering white particles, like powdered quartz." (P. 202, *Muspratt's Chemistry.*)

Hermann describes the process thus:—"Washing by sedimentation is a very suitable method of freeing quartz-sand from foreign admixtures, and it is particularly advisable when, as not infrequently happens, the chief impurity present consists of clay. It should be remarked that the silicates of alumina form glasses of unusually high fusing-point, and, therefore, they require to be got rid of, especially in the case of sand intended for the production of enamels. Sedimental washing is performed in a very simple apparatus, consisting of a wooden vat with tap-holes at different heights in the side. The vat being filled about two-thirds full with clean water, the latter is stirred to keep it in continual motion, and the sand is run in. When all the sand is in, the stirring is discontinued, and after waiting a few minutes, until the sand is judged to have somewhat subsided, the upper tap is opened. If clay is present in the sand, its particles will float longer than those of the quartz, and the water will run off very turbid. In this event the taps are opened successively until all the water is drawn off from the vat . . . . the operation being repeated until the water runs off quite clear. . . . . To prevent the washed sand from contamination, it is shovelled up with wooden shovels out of the vat, packed in strong linen cloths, and left to dry in the air, to be afterwards stored away in well-closed wooden cases until required for use. Iron shovels should not be employed, for the reason that the very hard quartz-sand wears away the iron, and even the small amount of iron thus introduced into the sand will impart a considerable degree of coloration to the glass prepared therefrom." (*Painting on Glass and Porcelain*, p. 86.)

The preparation of the gritstones of Staffordshire is simply the selection of the most suitable veins, breaking away all discoloured parts, chipping off all stains and vein-marks, and crushing to sand the selected portions in pans or mills. Softer formations, such as those of North Wales, East Staffordshire, and Derbyshire mountain-limestone pocket contents, may be reduced merely by drying slightly, and afterwards beating down with wooden mallets.

Properties.—Sp. gr., 2·5 to 2·65. Chemical symbol, SiO_2. Chemical composition, 98 to 99 or 99½ per cent. silica. Although chemically inactive at ordinary atmospheric temperature, silica is capable of performing the part of a powerful acid when intimate mixtures of it with basic oxides or minerals are brought under the influence of heat; in some cases reaction commences at

red-heat, in others only at high temperatures, varying according to the affinity of the components of the mixture.

Professor Rutley states that quartz is infusible before the blowpipe, and insoluble in all acids except fluoric acid. It is, however, more or less acted upon by a hot solution of potash. (*Study of Rocks*, p. 150.)

Professor Rutley also observes that "Quartz is seen frequently to contain inclosures of other substances, sometimes as crystals, sometimes in the form of lacunæ filled with liquids, etc. These inclosures are often visible to the naked eye, but the microscope commonly reveals their presence in vast number. The crystals of most frequent occurrence are those of rutile and chlorite." (*Study of Rocks*, p. 151.)

On the mineralogical scale of hardness, quartz is of the seventh degree, the point of a steel penknife producing no effect upon it. This hardness, coupled with the refractory nature of quartz-sand, renders it particularly serviceable to the decorative-tile maker as a means of keeping tiles separate during the firing.

The rational analysis of shales, marls, and clays shows the presence of quartz-sand, often in very fine state of division; and, in proportion, sometimes 52 per cent. or more.

Langenbeck specially comments upon two red-ware materials—one a shale, containing, by a rational analysis, 52·54 per cent. quartz; the other a clay, containing 21·57 per cent. quartz: the former a practical and useful material for pottery work; the latter shrinking, twisting, and cracking at the red-ware fire, and unable to take glaze without crazing. (*Chem. of Pottery*, pp. 59-61.)

But it must not be inferred from the foregoing that a standard proportion of quartz-sand is always necessary, for Langenbeck shows (p. 67, *ibid.*) that with yellow-ware clays good practical results accrue from the use of clays containing, by rational analysis, only 19·54 per cent. of quartz-sand.

In whiteware and white tile-bodies, quartz-sand has, in England, been almost entirely superseded by ground calcined flint. This, however, is not the case in the states of North America, where quartz and quartz-sand are used under the objectionable terms *Rock-Flint* and *Sand-Flint*.

In glazes, quartz-sand is useful by reason of its greater freedom and facility in mixing with other ingredients than wet-ground flint in its usual form.

Many years ago Professor Boys (Professor of Physics at South Kensington) demonstrated before the Royal Society that quartz could be melted by aid of the oxy-hydrogen flame, and spun into thread-like filaments, so fine as to be almost invisible even under a microscope. These quartz-threads proved themselves to be practically free from what is known as fatigue of elasticity, and found a use in instruments of precision and in the eye-pieces of astronomical telescopes. (See *Leisure Hour*, 1887, p. 568.)

Subsequently other experimenters entered the field, and eventually the

melting of quartz became a commercially practicable operation, which, during the last few years, has been developed at Hanau, near Frankfort, where quartz-glass apparatus is now manufactured for sale. (See *Pottery Gazette*, May 1903, p. 479.)

To enable crystalline quartz to bear the sudden attack of the oxy-hydrogen flame without danger of bursting, the pieces must first of all be slowly heated to a temperature of 1000° C. and then thrown into water. After this preliminary treatment quartz may be brought under the influence of the oxy-hydrogen flame, and raised to its melting-point at above 1700° C. (the melting-point of platinum).

The working of molten quartz is said to present no difficulties, apart from the fact that the material melts only at a very high temperature. Quartz-glass is said to be no longer sensitive to great and sudden temperature changes, even when not annealed. And it has other advantages over ordinary glass; for instance, (1) greater infusibility; (2) shows no after-effects of heating to temperatures up to 1000° C.; (3) its co-efficient of linear expansion is about one-seventeenth that of ordinary glass at temperatures from 0° to 1000° C.; (4) even in moist air quartz is an electric non-conductor; (5) it is not sensitive to the action of ordinary acids; (6) it is said to possess greater transparency than glass. (See *Thonindustrie Zeitung*, No. 129, 1901, p. 1931; and *La Nature*, 16th May 1901.)

These are portentous facts for ceramists and glassmakers. The practical bearing of the matter may be deduced from the news that the manufacture of utensils of quartz-glass is now being effected at Hanau, near Frankfort, and that such apparatus is already on the market commercially.

Flint.—To antiquarians the term "flint" brings up thoughts of remote past times when human needs and fancies were crudely ministered to by aid of skilfully fashioned flint implements.

To ceramists the term merely suggests one of the commonplace materials of every-day use, namely, the substance resulting when selected black flints are calcined and afterwards finely ground. Strange to say, the blacker the flints appear before burning, the whiter they usually are afterwards; consequently the ingredient known as "ground flint" is intensely white.

Prof. C. F. Binns, in his *Story of the Potter*, accredits Dwight, of Fulham, A.D. 1689, with being the first to use calcined flint in the manufacture of pottery. It is not stated how he became acquainted with this material, nor is the material mentioned in either of Dwight's patents—1671–1684; but there are many chalk-pits in the South of England where flints might easily be accidentally passed into the chalk-lime kilns and become burnt; and it is not improbable that, in the course of his searches for clays, calcined flints were brought under Dwight's notice, and as a potter he could hardly fail to be interested by their whiteness and refractoriness.

The material was subsequently introduced into Staffordshire by Astbury the younger, about A.D. 1720. It is said that "While travelling to London on horseback, in the year 1720, Astbury had occasion, at Dunstable, to seek a remedy for a disorder in his horse's eyes, when the ostler of the inn, by burning a flint, reduced it to a fine powder, which he blew into them. The potter, observing the beautiful white colour of the flint after calcination, instantly conceived the use to which it might be employed in his art." (Parke's *Chemical Catechism.*) Whether correct or otherwise, this pretty little tale savours strongly of the romantic. Possibly Astbury the younger inherited the astuteness that earned for his father unenviable fame in connection with Elers Brothers, for flints are not so easily calcined to intense whiteness, nor so easily reduced to a fine powder, as the Dunstable tradition presupposes; and if they were, flint-particles would surely be a desperate remedy for inflammation of the eye, animal or human; if one may judge by personal experience, we should say flint-particles are painfully wounding rather than curative.

Astbury the younger, be it observed, was journeying to London, which circumstance renders it probable that he would visit Fulham, and it is more likely he learned the use of calcined flint at Fulham than at Dunstable. Be that as it may, Astbury the younger introduced the material into Staffordshire, and it is perhaps ungrateful for an old flint-grinder to criticise the report of its discovery too severely.

Several varieties of flints are met with in nature: chalk-flints, beach or shore flints, and gravel-flints. Flints may be black, opaline, or brown tinted, according to circumstances, but they are always more or less translucent, particularly when observed as a thin flake in a moistened condition. They have all, most probably, a common parentage in the flints of chalk formations; certain chalk-cliffs reveal well-defined horizontal successive courses of black flints, three or four feet apart, recurring regularly and persistently.

The inquiry as to how the flints came to be in such a situation is, of course, one for geologists, and must indeed be a most fascinating study.

Sir Charles Lyell, F.R.S., remarks:—"The origin of the layers of flint . . . . has always been found more difficult to account for than that of the white chalk. In modern coral-reefs no such siliceous masses are known to be forming. But here again the late deep-sea soundings have suggested a very probable source of such mineral matter. During the cruise of the 'Bulldog' . . . . it was ascertained that while the calcareous *Globigerinæ* had almost exclusive possession of certain tracts of the sea-bottom, they were wholly wanting in others. . . . . In several of the spaces where the calcareous Rhizopods are wanting, the microscopic plants called *Diatomacea* . . . . the solid parts of which are siliceous, monopolize the ground at a depth of nearly 400 fathoms. . . . . When such Diatomacea decompose, the alkaline waters

of the ocean can take up and hold in solution only a minute portion of the silica set free, so that an opportunity would be given for the remainder to form concretionary nodules." (*Elements of Geology*, p. 319, Murray.)

Albert V. Bleininger, B.Sc., has stated that quartz, when treated with milk of lime, is converted into the colloid variety, and thereby greatly increased in volume; and it is by some authorities assumed that the hardening of Portland cement is due to the formation of gelatinous silicic acid; for "on letting a large quantity of water act on Portland cement, the volume of the latter is changed to a colloid mass occupying thirty-three times the original volume." (*Trans. Am. Cer. Soc.*, vol. v. p. 81.)

In England chalk-cliffs occur on some of the coasts and river-banks of Kent, Essex, Sussex, Berkshire, Norfolk, and Yorkshire; and in Ireland on the north coasts of Antrim. At Grays (Essex) there are very large works manufacturing whiting or whitening from chalk; and the flints falling from time to time, as quarrying proceeds, are placed aside and selected into different grades, those having the blackest fracture often going to potteries.

But in the manufacture of white earthenware and tiles the flints most largely used are specially selected beach or shore flints known as *Boulder-Flints*. These are found on sea-beaches on the coasts of the English Channel, and probably originate from the *débris* of chalk-cliffs worn down from time to time by tidal action; the chalky flints getting washed out to sea, rolled about in the Channel, and eventually beached. The rolling denudes them of their chalky coating, removes angularity and irregularity of shape, and reduces them to the rounded form of large pebbles. A very noticeable selective action simultaneously occurs, resulting in the beaching of approximately similar sizes and forms at different parts of the coast, in so much that experienced flint merchants can often recognize at sight boulder-flints from certain localities; distinct characteristics of size and shape almost always predominating in the case of boulder-flints from the locality of Rye (Sussex), Newhaven (Sussex), Dieppe (France), Le Treport (France), large heaps of each of these being easily distinguished one from another.

Pickers go out from certain Channel ports in small boats to the grounds or beaches where flints are cast upon the shore, and, under experienced supervision, select the best boulder-flints and convey them home to port. The ports where this traffic is usually carried on are Newhaven, Shoreham, Rye, Ramsgate, Margate, Cromer, etc., on the English coast; and Dieppe, Fécamp, St. Valery, and Le Treport, on the French coast. At these centres the flints are accumulated, and from thence are shipped to the ports of the principal pottery-making centres, such as Runcorn, Glasgow, Newcastle-on-Tyne, Stockton-on-Tees, and certain other ports throughout the world.

Arrived at the potters' mills, the flints are washed with water in grid-barrows, and then calcined in conical kilns, much in the same manner as

limestone is calcined, *i.e.*, by means of thin layers of fuel alternating with layers of flints, the process of calcination taking place slowly and occupying several days to complete. There are, however, some slight variations in the manner of burning at different mills. When calcined, the flints are drawn from the bottom of the kiln, riddled free from dust, chippings, and cinder, and subsequently crushed and ground.

The grinding is usually effected in machines known as potter's flint-mills, specially designed to grind finely materials of great hardness with the least practicable degree of contamination, and with the least risk to the health of the workmen.

When the use of calcined flints was first attempted in Staffordshire potteries, they were ground dry or pulverized finely; it quickly became evident that the reputed cure for horses' eyes was a positive curse for human lungs.

Thomas Benson, who in 1732 obtained letters-patent for a wet-grinding mill, particularly mentions in his specification that "The common method hitherto used . . . . breaking and pounding the stones dry, and afterwards sifting the powder through fine lawns . . . . proved very destructive to mankind . . . . the dust . . . . fixes so closely upon the lungs that nothing can remove it. . . . . It is very difficult to find persons to engage in the said manufacture."

He had invented his wet-grinding mill in 1726, but its practical success was at first delayed, because he made the mistake of attempting to grind by means of iron balls. Subsequently, by the use of heavy siliceous stones for the grinding-surfaces, the mills became a success, and in principle Benson's mills remain in use to this day.

By the kindness of Messrs. W. Boulton, Ltd., of Burslem, we are able to illustrate in fig. 164 the form and construction of the Benson potter's mill as now in general use. These mills or "flint-pans" usually measure from 9 feet to 16 feet diameter.

They are worked continuously day and night, a charge being cast on the pan morning and evening with the proportionate quantity of water, which is supplemented by further addition of water as the grinding proceeds.

For a 10-foot pan the charge is about 15 cwts. morning and evening, larger pans taking larger quantities according to their grinding area, which may be calculated roughly as two-thirds of the square of the diameter, thus:— $10 \times 10 = 100 \therefore 66$, $14 \times 14 = 196 \therefore 130$; hence by calculation a 14-foot pan would take 30 cwts. But this varies according to the condition of the pan and the weight of "runners" (mill-stones), and the fineness to which the material is to be ground.

Upon completion of the grinding, the charge in a semi-fluid state is

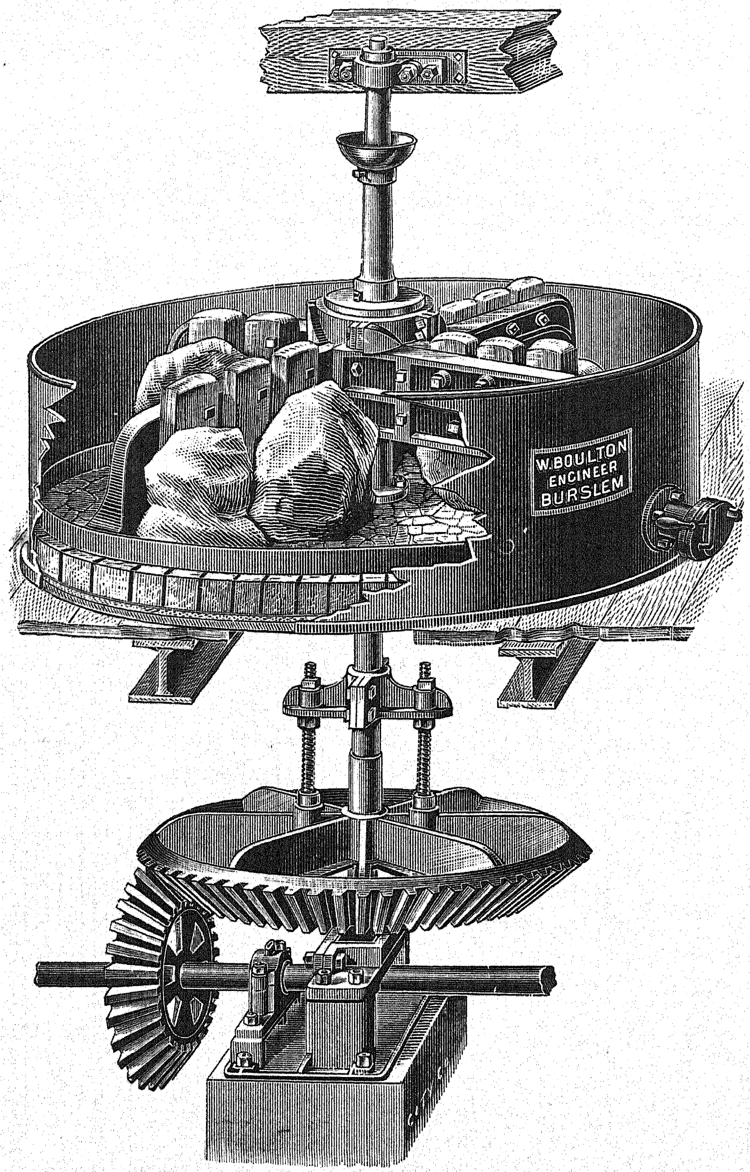


FIG. 164.—Wet-grinding flint-mill pan. (*By permission of Messrs. Wm. Boulton, Ltd., Engineers, Burslem.*)

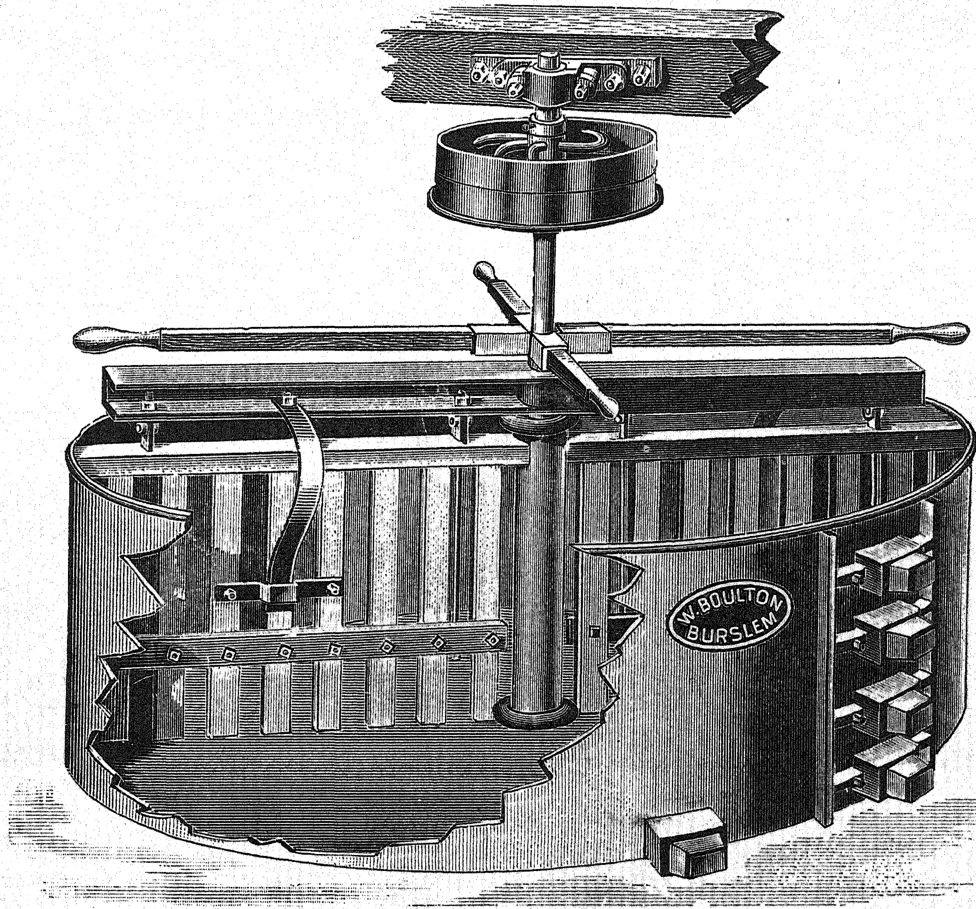


FIG. 165.—Ground-flint wash-tub. (*By permission of Messrs. Wm. Boulton, Ltd., Engineers, Burslem.*)

allowed to flow into an apparatus called a wash-tub (fig. 165). Here the material is mixed with a considerable volume of water, agitated, settled for a few minutes; the insufficiently ground particles are thus free to settle down to the bottom. The finely ground upper portion is then allowed to flow off into large underground "arks," where it thickens by sedimentation, the excess water being decanted by opening plugs fixed at different heights for this purpose.

But to return to the wash-tub, which is one of the most useful devices for separating the fine from the coarse. After the upper portions have been run off into the arks, the plugs are fastened in again; the apparatus again agitated until the coarse portion is stirred up into a creamy state; then a

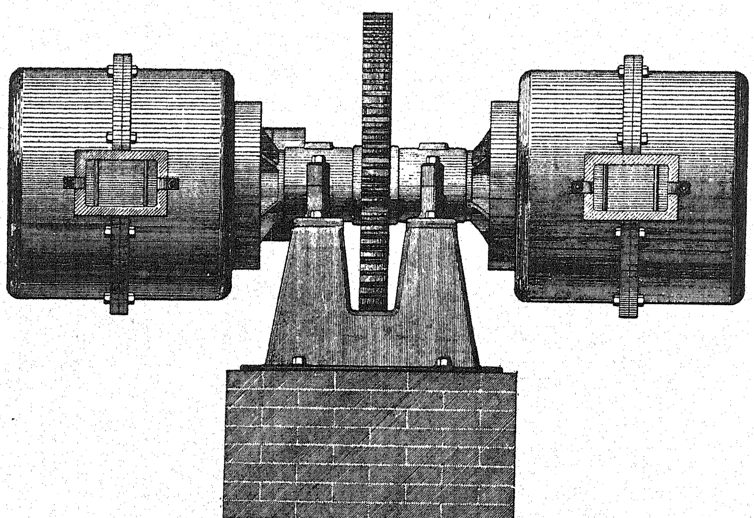


FIG. 166.—Duplex dry-grinding cylinders, 20-inch (*lined with hickory or porcelain blocks*). (*Made by the Crossley Mfg. Co., Trenton, N.J., U.S.A.*)

lower plug is opened and the coarse semi-fluid "knockings" or "trailings" are allowed to flow out of the wash-tub into a "knockings" or "knottings" tub, and this is hoisted up to the mill-pans, and thus the unground portion is again run on the pans along with a fresh charge of flints to be reground. Thus extreme fineness is attained without dust, loss, or sieving.

Other kinds of mills or grinding-machines are also used for reducing to a condition of extreme fineness calcined flints, felspar, and other hard potters' materials. Of these the Alsing cylinder type, in which grinding is effected by means of flint pebbles or porcelain balls, rolling within cylinders, is perhaps most usual. The cylinders are of iron lined with either porcelain bricks or wooden blocks. By means of these cylinders or ball-mills, the materials may

be ground wet or dry at the option of the user, suitable provision being made for charging and emptying accordingly.

In the United States of America these mills have found great favour, and are the rule rather than the exception. Professor C. F. Binns, M.Sc., of the Alfred University, kindly informs me that the pebbles for the larger-sized mills are simply raw flints, and for the smaller sizes porcelain balls about 1-inch diameter. The charge of pebbles is a little more than half the capacity of the mill, and the charge of material about the same weight as the pebbles. Time of grinding from a half to two hours. He further states that for a wet charge the mill must not be more than three-quarters full, and for a dry charge less. The apparent unconformability of this note with the charge-weights previously given is accounted for by the fact that the interstices between the pebbles become partially occupied by material. A heavy mill will deal with material in $\frac{1}{4}$-inch fragments, but for small sizes he would sift the material through a $\frac{1}{8}$ sieve prior to charging it into the ball-mill for grinding.

The Crossley Manufacturing Co., of Trenton, N.J., who kindly lend a block for illustrating this kind of mill, arranged as a twin mill (see fig. 166), advise two hundred pebbles about 2-inch diameter in a 20-inch mill; and about forty pebbles of $1\frac{1}{2}$-inch diameter in a 10-inch mill; the charge for a 20-inch mill being about 150 lbs., and for a 10-inch mill about 25 lbs. And they advise that the mills be filled to nine-tenths of their capacity.

The Abbé Engineering Co., of 220 Broadway, New York, also supply grinding-mills of this type; their No. 5 pebble-mill is illustrated on p. 345, open, and also encased in galvanized-iron cover.

By a special construction their mill can be separated into two halves for convenience when relining the interior (fig. 169). They claim that no other mill than a pebble-mill presents such an enormous grinding-surface within such limited space, and that no parts require dressing or sharpening. Also that porcelain presents the best possible grinding-surface, and will neither contaminate nor discolour the material being pulverized.

Moreover, that these machines will pulverize either wet or dry material, delivering a perfectly uniform product without bolting.

Their directions for operating the mills are as follows:—"When the cylinder is mounted . . . . and encased in such a manner that the bearings are outside the casing, a certain amount of pebbles (sufficient to nearly half fill the cylinder) is put in. A charge of material (equal to about the bulk of the pebbles) is then fed into the cylinder, and the opening closed with the tight cover. The mill is then revolved at the proper speed until the material is pulverized fine enough. The tight cover is then removed, and after the grate discharge cover has been put in its place, the cylinder is started running, by which operation the pulverized material will pass through the openings in the grate, and the pebbles or balls be retained in the cylinder. It

will take from two to five minutes to discharge, after which the grate is taken off and the cylinder is ready for another charge."

If the cylinder is used for wet grinding, for instance, on paints, enamels, glazes, etc., the operation is the same as the above, except that, when discharging, a tight cover provided with a valve is used instead of the grate discharge cover. The cylinder is turned with valve downward, and the latter opened so as to allow the material to run into any receptacle.

With regard to the nature of the pebbles, the Abbé Co. remark that soft or brittle pebbles not only wear out very rapidly in the machine, but also deteriorate the quality of the material being pulverized. Pebbles of uniform round or oval shape are preferable; and selected Greenland flint pebbles are claimed to be the hardest, toughest, and most durable.

The following particulars of pebble-mills from the Abbé Engineering Co.'s Catalogue may be useful for reference and comparison:—

No.	Outside Dimensions of Cylinder.	Charge, taking Sand as Unit.	Weight of Cylinder.	Floor-space Required.	Pebbles Furnished.	Approx. Power Required.	Size of Pulleys.	Speed of Cylinder, Revolutions per Minute.
1	6′ × 5′	2800 lbs.	8000 lbs.	11′ × 12′	4200 lbs.	12 H.P.	30″ × 10″	18
2	5′ × 4′	1500 ,,	6000 ,,	7′ × 8′	2450 ,,	8 ,,	28″ × 8″	25
3	4½′ × 3½′	800 ,,	5000 ,,	6½′ × 7½′	1400 ,,	5 ,,	24″ × 6″	30
4	3¾′ × 3½′	500 ,,	4000 ,,	6′ × 7½′	1050 ,,	4 ,,	45″ × 6″	35
5	3′ × 3½′	300 ,,	2000 ,,	5′ × 7′	700 ,,	2 ,,	36″ × 6″	40
6	30″ × 30″	200 ,,	1200 ,,	4′ × 5′	350 ,,	1½ ,,	24″ × 4″	44
7	30″ × 18″	120 ,,	800 ,,	4′ × 4′	350 ,,	1 ,,	24″ × 4″	44

Somewhat similar mills are made by English engineers also, and are well illustrated in the Catalogue of Messrs. W. Boulton's, Ltd., of Burslem, Staffordshire.

Several years ago a pneumatic machine, invented by an American, was put into operation at Burslem by Mr. Anthony Shaw, afterwards by the North Staffordshire Pneumatic Pulverizer Co.; and millers of the "old order," working with "Benson" mills, were given to understand that their method was doomed, and would quickly be a thing of the past. However, events were not so cruel; the stern reality of actual working ended in the abandonment of the "pneumatic" machines. The old wet-grinding flint-pans, originally invented by Benson nearly two hundred years ago, still retain the confidence of the trade in North Staffordshire.

Recent scientific investigations, conducted by Professor C. F. Binns, of Alfred University, New York, into the evidence and causes of the superiority of wet-ground ceramic materials, are recorded at considerable length in vol. v. of *Trans. Am. Cer. Soc.*, pp. 281, 292.

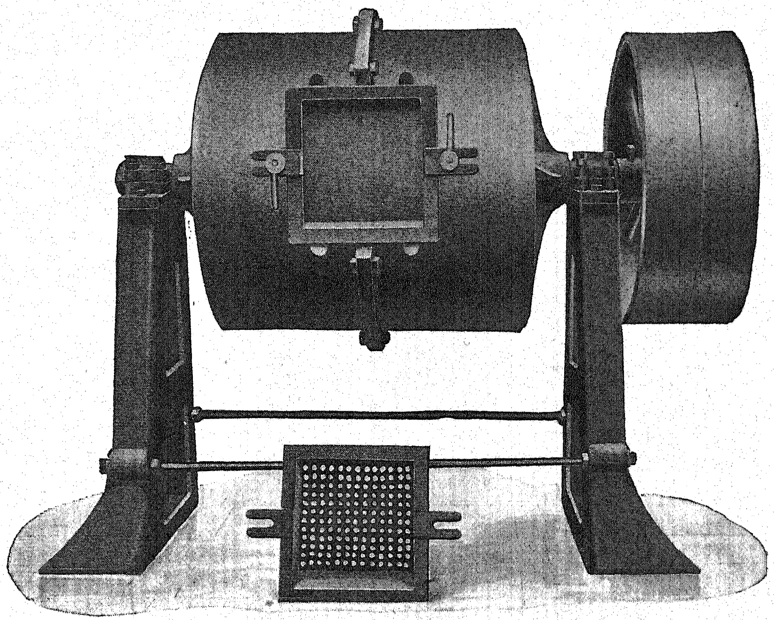


FIG. 167.—Abbé Engineering Co.'s No. 5 pebble-mill.

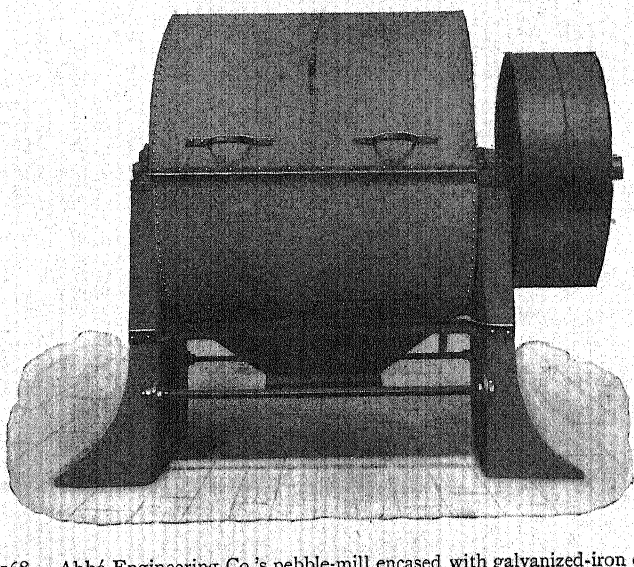


FIG. 168.—Abbé Engineering Co.'s pebble-mill encased with galvanized-iron covers.

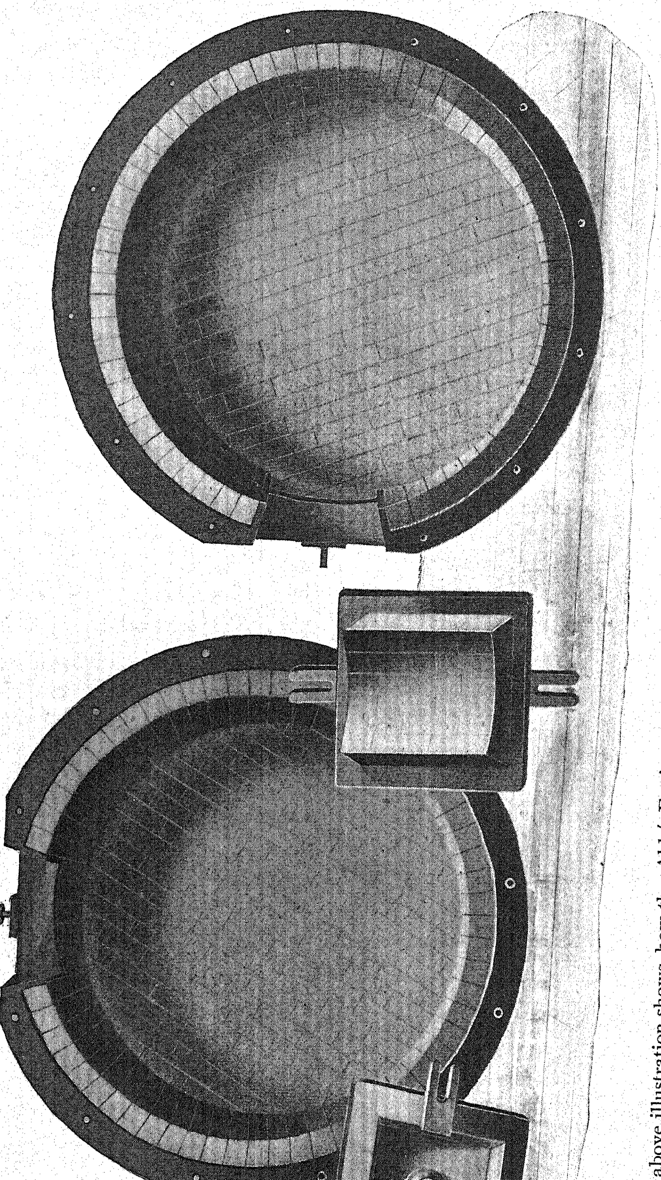


FIG. 169.—The above illustration shows how the Abbé Engineering Co. build their No. 7, No. 6, and No. 5 pebble-mills (in halves). This construction, it is claimed, adds greatly to the convenience in relining, enabling the lining of each head and half to be done separately and in full view of the man doing the work, so that each block can be laid in proper position securely.

Four series of bodies were prepared, and test-pieces made up of them were burnt; with the results indicated by the condensed tabulated statement below, which is from Professor Binns' paper, but arranged in a more concise form:—

Series.	No.	Kaolin.	Ball-clay.	Flint.		Spar.		Results of Body Tests.		
				Sifted.	Ground.	Normal.	Ground.	Texture.	Colour.	Ink Test.
I.	1	20	30	40	...	10	...	Granular.	Cream.	Slowly absorbed.
	2	20	30	30	...	20	...	Do.	Stony.	Slightly retained.
	3	20	30	20	...	30	...	Do.	Stony.	Do.
II.	1	20	30	...	40	10	...	Dense.	Cream.	Slightly absorbed.
	2	20	30	...	30	20	...	Porcellaneous.	Stony.	No absorption.
	3	20	30	...	20	30	...	Do.	Stony.	Do.
III.	1	20	30	40	...	...	10	Granular.	Cream.	Slightly absorbed.
	2	20	30	30	...	...	20	Do.	Stony.	Slightly retained.
	3	20	30	20	...	...	30	Do.	Stony.	Do.
IV.	1	20	30	...	40	...	10	Dense.	Cream.	Slight absorption.
	2	20	30	...	30	...	20	Porcellaneous.	Stony.	No absorption.
	3	20	30	...	20	...	30	Do.	Stony.	Do.

With regard to Series II. and IV., Professer Binns, among many other instructive things, significantly observes that "The granular fracture is lost, and in its place there is a fine porcelain texture upon which the ink has no effect whatever." (*Trans. Am. Cer. Soc.*, vol. v. p. 290.)

"The Effect of Varying Fineness of Particles of Non-plastic Materials in Pottery Bodies" has been the subject of careful investigation by Mr. Arthur Heath, who read a paper describing his researches and results before the N.S. Ceramic Society at Victoria Institute, Tunstall, 13th December 1902. (See *Trans. N.S.C.S.*, vol. ii. p. 31.)

Mr. Heath apparently overlooked the fact that even as far back as the time of Josiah Wedgwood the effect of fineness of grinding potters' materials had been a subject of concern, inquiry, and experiment. (See *Josiah Wedgwood's Letters to Bentley*, vol. ii. p. 165.)

But without attempting to discuss such an excellent paper, it may be noted that, while demonstrating that defects such as "eggshelly" surface of the glazed ware and crazing may result from coarseness of the flint, he also demonstrates defects arising from excessive grinding; and goes so far as to recommend that the excessively fine portions should be separated out and put to some use other than for bodies.

The conclusions arrived at from the investigation were:—

1. The flint in an earthenware body causes the contraction to vary inversely as the diameter of its grains.

2. The porosity varies directly with the diameter to ·05 mm.; below that it varies inversely as the diameter.

3. The effect on the glaze is that the tendency to craze increases with the size of the grains of flint!

4. The stone in an earthenware body causes the contraction to vary inversely as the diameter of its grains.

5. The porosity varies directly as the size of grain.

6. The effect on the glaze does not tend to crazing, but the eggshelly effect diminishes with the size of grain; but when the stone is less than ·029 mm. diameter, it causes a blistering of the body when glazed.

7. The size of grain in the body does not produce "spit-out" ware. (*Trans. N.S.C.S.*, vol. ii. p. 45.)

The comparative ease with which calcined flints may be reduced to an almost impalpable powder, and without any considerable degree of contamination, by means of these special contrivances and mills, in conjunction with its intense whiteness and purity, and its rigidity, refractoriness, and absence of shrinkage under fire, cause this material to be used in very large quantities in the preparation of bodies for white earthenware and tiles; so much so that ceramic wares of this class are now frequently designated flint-wares.

Properties.—Sp. gr., 2·5. Chemical symbol, SiO_2. Chemical composition, 97 to 98 per cent. silica, small quantities of lime carbonate and moisture making up the difference. It has been observed in practice that often the bleached whitish-coloured boulders fly off in chippings during the process of calcination more readily than the solid, round, blacker boulder-flints, and that they register a lower sp. gr. It has been surmised that both these phenomena arise from partial hydration taking place while the flint is exposed on the beaches, but researches have not been carried far enough to establish this.

The loss on drying an ordinary commercial sample of ground calcined flint, *i.e.*, ground by the wet process and subsequently dried on a kiln, is usually about 3 per cent., and there is practically no further loss on calcination. The material frequently yields slight effervescence when tested with dilute hydrochloric acid, on account of the small quantity of lime carbonate abraded from the chert mill-stones or "runners" during grinding. If, however, more than 1 per cent. of lime carbonate is found, the material should be regarded with suspicion and further tests and inquiry made.

Calcined flint of the usual standard quality is highly refractory, and of most intense whiteness. When heated in intimate contact with alkalies or lime or lead oxide, fusion takes place and silicates are formed; hence its service in compounding glazes. On the other hand, when fusible ingredients

are largely absent, and the temperature does not exceed the limits customary in whiteware potters' kilns, it is not vitrified; hence its service in white earthenware bodies, and as a parting wash for saggars and cranks.

Some interesting notes upon the behaviour of flint when subjected to successive burnings are to be found in the *Pottery Gazette*, May 1903, p. 502, being excerpts from lectures by Mr. W. Jackson, A.R.C.S., instructor in pottery to the Staffordshire County Council.

By certain diagrams it is demonstrated, first, on the authority of Cramer, (of Charlottenburg), that sp. gr. falls continuously from 2·66 in the raw flint to 2·398 after the tenth firing, and that this coincides with an increase in volume; and second, on the authority of Le Chatelier, that the change of volume in the case of amorphous silica is much less in degree, and far more regular in progression, than that of crystalline silica. From these investigations it is assumed that amorphous silica is best for potters' use. The advantages therefore of calcination of flint are twofold, viz., reducing the difficulty of grinding, and reducing the risks of fracture in the ware. It is therefore reasonable to infer that, whenever either flint or quartz is used in ceramic bodies, preliminary calcination is advantageous.

Whitening, Paris White, Lime Carbonate.—For the purposes of the potter, these may be considered synonymous terms indicating only slightly different commercial forms of carbonate of lime, some of the preparations being obtained from chalk and some from mountain limestone. Only the purest should be made use of in ceramics.

In Peak Forest district, near Buxton, a certain seam of very white limestone is found at a considerable depth from the surface, and this is separated from contiguous strata of less pure limestone, and placed aside for chemical uses, as distinguished from blast-furnace limestone. This quality yields on analysis 98·87 per cent. of carbonate of lime.

From pure white limestone such as this, whitening for potters is prepared by simply grinding the stone finely on wet-grinding mills like the flint-mills already described, and subsequently drying the product. Sometimes it may be ground or finely pulverized in a dry state, if the mills are such as effect this without colourant contamination. An even purer limestone, showing 99·8 of $CaCO_3$, is found at Ash Grove, near Kansas City, Mo., U.S.A.

Properties.—Sp. gr., 2·6 to 2·7. Chemical symbol, $CaCO_3$. Chemical composition, 55·5 lime, 43·5 CO_2. Loss by calcination or fusion with other ingredients, 47 per cent. Soluble in dilute hydrochloric acid, with very violent effervescence. When more than 2 per cent. resists solution in dilute acids, the parcel concerned should not be used until further tests and inquiries have been made.

Free calcium oxide alone is highly refractory; it follows then that the

proportion of whitening introduced in a glaze-frit must be carefully regulated according to the silicic and boric acids present, and its relation to any other bases forming part of the composition.

Dolomite, *i.e.*, calcium-magnesian limestone, has been tested, in comparison with whitening, by several American ceramists (see *Pottery Gazette*, November 1901); but their results warrant no changes in that direction by ceramists so long as a pure quality of whitening from pure limestone is obtainable. The use of whitening in glazes burned at high temperatures, such as those used for hard porcelain, enamelled bricks, and fireclay wares, and what is called Bristol glazed stoneware, wherein the compounds of lead and of boric acid are generally absent, proves whitening to be a powerful flux for silica at high heats.

Plaster of Paris.—Potter's plaster is a variety of plaster of Paris; that is to say, a prepared product of mineral gypsum.

Gypsum is a native hydrous sulphate of calcium. In the British Isles its occurrence usually coincides with that of red marls of the Keuper beds of triassic rocks. It is sometimes associated with rock-salt, as at Droitwich, where gypsum is said to form the roof of the brine reservoir. (*Geol. England and Wales*, p. 296, Kelly.)

In England gypsum is now principally derived from the following counties: Nottinghamshire, Cumberland, Staffordshire, Sussex, and Derbyshire, smaller quantities being raised in Somerset and Westmorland. The total output for 1901 was stated to be 200,766 tons.

Gypsum also occurs in Eocene or Purbeck formations, as at Montmartre, near Paris, whence our appellation plaster of Paris; and near Netherfield, Sussex, where the gypsum is 35 feet thick.

Fine semi-crystalline forms of gypsum are called alabaster; this is found in the province of Pisa (Italy), and extensively used for making ornaments. "The purest white alabaster is worked by underground excavations in the Val di Marmolaio, near Castellina, twenty-five miles from Volterra in Tuscany." (*Handbook, Mus. Pract. Geol.*, 1896, p. 28.)

In Canada very considerable quantities of gypsum have been found, chiefly in New Brunswick and Nova Scotia, the export for 1902 aggregating 268,480 tons, chiefly to the United States.

"The largest deposits of gypsum known in Canada at present are those of Hillsborough, in Albert County (New Brunswick), where extensive quarries have been opened, and whence great quantities have been and still are being removed for calcination and exportation. The mineral is usually met with in very irregular masses, associated with red marls, sandstones, and limestones, at or near the summit of the series, and varies much in character. Thus at Hillsborough, in the quarries now being worked, there is exposed a total head of rock of from 90 to 100 feet, of which about 70 feet, forming the

upper portion, consists for the most part of 'soft plaster' or true gypsum, which rests on beds of 'hard plaster' or anhydrite of unknown thickness. . . . . At Petitcodiac, where the deposit has a breadth of about 40 rods and a total length of about one mile, the whole is fibrous and highly crystalline, and is traversed through its entire extent by a vein of nearly pure selenite, 8 feet wide.

"Gypsum occurs in Nova Scotia in very extensive deposits, varying in thickness from a few inches to 120 feet. These deposits are found in the carboniferous system." (*Economic Minerals of Canada*, pp. 214, 215, Canadian Comr., Glasgow Exh., 1901.)

In the United States the output of gypsum reached the enormous figure of 659,659 short tons (2000 lbs. each) in 1901, and of the value of $1,577,493.

The states yielding the greater portion were thus:—

Iowa, Kansas, Texas,	213,419 short tons.
Michigan,	185,150 ,,
New York,	119,565 ,,

Other states making up the balance in very much smaller quantities.

In the report on the *Mineral Resources of the United States, 1901*, there are statistics of the world's production of gypsum from 1893 to 1900, from which we learn that the comparative output in 1900 was as under:—

United States of America,	594,462 short tons.
Great Britain,	233,002 ,,
Canada,	252,081 ,,
France,	1,761,835 ,,
Algeria,	41,446 ,,
German Empire,	39,103 ,,
India,	4,865 ,,

Preparation.—The mining or quarrying is variously effected according to circumstances, either by open workings or by driving levels from vertical shafts. The gypsum-masses are shattered by blasting, and when raised to the surface the rock is scrupulously examined and selected, usually into four qualities. The purest, whitest, sugar-like portions of the stone, *i.e.*, the "*Best Fine White*," is not generally sold to potters, but a slightly stained and veiny quality, rather harder and somewhat discoloured, is placed aside as the "*Potter's Plaster Stone.*" In each case the mineral is freed from adhering marl, etc., and washed with hot water. The gypsum is then broken into smaller lumps and passed through stampers and crackers; afterwards this is "kibbled" in a mill of the type of a flour-mill (at least, this used to be so), preparatory to being passed into a self-feeding mill, where it is ground "fine,"

or finished in a manner similar to the old-fashioned method of grinding flour between flat mill-stones. The ground gypsum is then conducted on to a heated kiln-floor of fireclay quarries, and "boiled," *i.e.*, heated carefully to a temperature of about 120° C. (248° F.), to drive out the water of crystallization. It is of greatest importance not to overheat the material at this stage; for, if allowed to attain a temperature of 200 C., it becomes "dead-burnt," and would set too slowly. When the kiln process has been completed, the "*Boiled Plaster*" resulting is carefully placed in convenient bags ready for delivery, and should be very judiciously warehoused, free from damp, to keep it in good condition. The products of some mines yield a plaster too soft when set for potters' use, and these sources must be avoided. In the *Handbook to the Museum of Practical Geology, London,* it is stated that "To ensure rapid consolidation it is desirable to so perform the calcination that about 5 per cent. of water is left in the plaster. Good plaster of Paris is far from being an anhydrous sulphate." (*Handbook*, p. 30.)

Usually it is said that white plaster casts better than pink plaster, but that pink plaster makes the hardest moulds. Tendency toward producing a pinholey surface, and differences in comparative contraction and expansion of plaster of Paris, are also matters for consideration.

"*Baked*" *Plaster* is the term applied to plaster of Paris prepared by heating selected and washed lump gypsum-stone in kilns for about five hours prior to grinding. This method used to be largely adopted at a works at Newark-on-Trent, where some four hundred tons a week were made; and under this system it was claimed that out of two and a quarter million sacks not one sack had been returned as deficient in quality.

Keene's Cement.—According to the *Handbook to the Mus. Pract. Geol.*, Keene's cement is prepared thus:—"Dissolve 1 lb. of alum in a gallon of water; this solution is used for soaking 84 lbs. of gypsum calcined in small lumps. These lumps are then exposed for eight days to the air, and afterwards calcined at a dull red-heat, and then ground and sifted."

Parian Cement is prepared by soaking the plaster in a solution of borax instead of one of alum. (*Handbook, Mus. Pract. Geol.*, *1896*, p. 41.)

Properties.—Sp. gr. of gypsum, 2·28 to 2·33 (Hurst). A chemical analysis of gypsum from the Trent district in Derbyshire has been given as under:—

Calcium sulphate,	67·66 per cent.
Water,	20·10 ,,
Silica,	2·73 ,,
MgO,	0·66 ,,
Fe_2O_3,	slight ,,

Another analysis of gypsum-stone largly used by potters is:—

Sulphate of lime,	78·99 per cent.
Water of combination,	21·01 ,,

Analysis of a quality of plaster of Paris supposed to be specially suitable for potters' use:—

Calcium sulphate,	92·05
Water,	7·05
Magnesia,	0·76
Silica,	0·05
Alumina,	0·09

When carefully prepared it acquires the valuable property of taking up a considerable volume of water, and solidifying with it in a very short time into a compact, white, porous, firm mass, taking any form into which it has been directed by its surroundings. When once set it also has the further property, arising from its porous character, of remaining comparatively hard and insoluble and unaffected, even when moist substances or much water are subsequently allowed to act upon it. But to secure this the plaster must, after wetting and setting, be allowed to become almost perfectly dry before being used in the manner indicated. When this is attended to, moist clay may be applied to the resulting forms of the plaster—*i.e.*, to the plaster-moulds—water is absorbed from the plastic moist clay, and when the clay-ware is removed from the mould the plaster will part with the absorbed water and become dry again, ready for repeated use. In a sense this absorption and evaporation may be likened to the action of a sponge.

In practice it has been observed that, in the process of setting, when the water and ground plaster of Paris have been mixed together a short time, a certain amount of heat is evolved by some action associated with the setting together of the plaster and the water; and that, unless this heating rises to a certain temperature (not definitely specified by the observer), the resulting plaster-mould is not firm and durable.

Again, experience shows that some plaster of Paris swells more than others when setting, and that different plasters yield different sizes of moulds, even when cast from the same model. Whenever moulds are required to fit rigid receptacles, such as jigger-heads, etc., this feature has to be taken into consideration.

For potters' use, plaster of Paris, of a slightly pink shade of whiteness, is generally preferred, and usually sets harder, and will bear knocking out of the frames better than the very white plasters.

Fineness, freeness, freedom from lumps of congealed plaster, dryness, are all points to look for in examining plaster; and when set the resulting moulds should be rather hard to cut, and should have a good fine surface which will yield smooth clay-wares and will wear well.

When an intimate mixture of anhydrous calcium sulphate with anhydrous potassium sulphate is stirred up with less than their weight of water, the mass becomes so suddenly solid that it cannot be poured out of the vessel. If four

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or five parts of water are employed, then the compound sets more slowly, yet still quicker, than plaster of Paris.

Plaster of Paris is sometimes used both as a constituent of glazes, particularly those used for enamelled bricks and fireclay wares, and in the engobes or enamel bodies for these wares.

Also it appears as a useful ingredient in some of the whitest "Barbotine" slips for underglaze decoration.

Barytes.—In the British Isles heavy spar, or barytes, is chiefly found in the lead-mines of Shropshire (Snailbeach and Wotherton); smaller quantities being raised in Durham, Derbyshire, Yorkshire, Wales, Scotland, and Ireland; impure varieties, known as cawkstone, being comparatively common in Derbyshire.

The only treatment barytes undergoes for use in tilemaking is careful selection and grinding; although for some purposes a quality called bleached barytes, which has been treated with acid to dissolve out impurities, is available.

Properties.—Sp. gr., 4·0 to 4·7. Chemical symbol, $BaSO_4$. Chemical composition, 65 per cent. barium oxide, 34 per cent. sulphuric anhydride. Loss on calcination of commercial sample, about 2 or 3 per cent. When calcined with charcoal at a white heat, it is decomposed, and barium sulphide formed. Alone, it may with difficulty be fused into a hard white enamel, which is said to be practically insoluble in acids at ordinary temperatures.

The introduction of this material is attributed to Josiah Wedgwood, who by its aid prepared his world-renowned Jasper wares.

Barium Carbonate.—Witherite, the native carbonate, in England is chiefly found in Northumberland, at Fallowfield near Hexham, and at Settlingstones near Fourstones, these sources yielding seven thousand tons in 1901. But, as a rule, the chemically prepared precipitated form of carbonate of barium is probably most generally used, where necessary, for ceramic purposes.

This is a very elegant preparation in condition and appearance, and contains from 96 to 98 per cent. of barium carbonate; the difference consists mostly of sulphates, sulphites, and hyposulphites. The loss on calcination or fusion in a frit-compound is about 25 per cent.

It is a heavy white powder, sparingly soluble in water, but dissolves with effervescence in dilute hydrochloric or nitric acid, the solution yielding dense white precipitate with sulphuric acid.

The poisonous character of several of the salts of barium, however, renders this an undesirable ingredient, and its use should be avoided and discouraged as much as possible.

Apart from this, the practical results of its use are not always satisfactory. In my own experience I cannot remember ever using it in glazes or enamels with any success unattainable by other means; and in the report of a long

series of carefully conducted experiments by American ceramists they say:—"In all combinations in which we used it the glazes were scummy and worthless. . . . . No single glaze in which BaO was used in any proportion was workable." (*Pottery Gazette*, November 1901.)

Fluor-Spar.—In the *Mines and Quarries Report for 1901*, Part III., the only counties mentioned as raising fluor-spar in Great Britain are Durham and Derbyshire, the former county being by far the greater contributor to the total output of 4214 tons; the Weardale Lead Co., of Stanhope, Durham, raising from their two mines an aggregate of 3206 tons.

It is not stated whether Derbyshire "Blue John" is any better for ceramic purposes than the Durham quality; and as far as the writer knows the only preparation is grinding either by the wet or dry methods.

Properties.—Sp. gr., 3·0 to 3·25. Chemical symbol, CaF_2. Chemical composition, when pure, 51·3 calcium and 48·7 fluorine.

On charcoal by blowpipe test it fuses to a clear bead, which becomes opaque on cooling.

In many experiments with this ingredient as an assistant to fusion, my results have been very disappointing; but for some more or less occult reason it is a serviceable ingredient in connection with pink and crimson colours and glazes. When whitening is used in a compound, oxide of calcium—lime—is probably the ultimate state in which union must be effected with the other ingredients. On the contrary, when fluor-spar is introduced, whatever becomes of the fluorine, if the mineral is chemically decomposed at all, it is quite possible that calcium may act in a nascent condition, and results may not always be identical with those of lime.

Cryolite.—Cryolite is found native at Evigtok, in West Greenland, where it forms a vein in the gneiss-rock. According to the report by the United States Geological Survey, it occurs in great snow-white masses which are partially transparent. "It constitutes a large bed in a granitic vein in gray gneiss. The cryolite is limited to the granite, and the richer portion is about 500 to 1000 feet in area. Associated with the cryolite in small amounts are quartz, beautiful crystals of siderite and galena, smaller amounts of sphalerite, pyrite, chalcopyrite, and wolframite, which are irregularly scattered through the cryolite. Surrounding this richer portion there is a zone where the chief minerals are quartz, feldspar, and avigtite, a variety of muscovite-mica. Besides these there are fluorite, cassiterite, and arsenopyrite, all of which are in a kind of basic ground-mass of cryolite. Between this outer zone and the main mass of the cryolite, the contact is rather sharply defined; but there is no distinct boundary between the outer zone and the surrounding granite into which it passes. The mineral is mined by open-cuts, and forms a quarry that is about 600 feet in length by 200 in width and 100 feet or more in depth. Whole cargoes of mineral that were 99·5 per cent. pure cryolite have

been obtained from the inner and deeper portions of the quarry." (*Mineral Resources of the United States, 1901*, p. 883.)

For ceramic purposes, careful selection and grinding in manner that will leave the product free from contamination is all that is required in the way of preliminary preparation for use as cryolite. When, however, it is desired to make it a base from which to prepare alumina, the preparation will be as described in the following paragraph on alumina.

Properties.—Sp. gr., 2·9 to 3·0. Chemical symbol, $3NaF + AlF_3$. Chemical composition, 13·0 Al, 32·8 Na, 54·2 F.

It is a fluoride of sodium and aluminium, which in appearance somewhat resembles snow or finely grained lump-sugar.

Fuses before the blowpipe, and reacts for alumina when tested on charcoal with nitrate of cobalt.

In ceramic glazes it is occasionally useful to overcome opalinity, in the way alumina does, when alumina itself is too refractory; but is less effective and induces crazing when in excess.

From the report above mentioned, we learn that "Cryolite is also used to a limited extent in the manufacture of an opalescent glass which resembles French porcelain. This glass is made from a mixture composed of two parts of powdered cryolite and one of sand (silica), with one-half an equivalent portion of zinc oxide. The resulting opalescent glass is extremely hard and tough." (*Mineral Resources*, p. 884.)

Whatever purposes cryolite is used for, care should be taken to suitably provide for the fluorine evolved during chemical reaction. It will be observed that cryolite contains about 54 per cent. fluorine, a large portion of which may be disengaged upon fusion with other ingredients.

Alumina.—Free alumina is not of very frequent occurrence in nature; its most common forms are corundum, ruby, sapphire, and diaspore. But in association with silica as kaolinite, it is a component of abundant and widely distributed rocks; and its hydrate, in association with hydrate of iron, is largely mined in France, Ireland, and America. Clays, brick-earths, granites, felspars, cryolite, corundum, bauxite, alunite, and alunogene all contain alumina. The alumina that is used in the ceramic industry, however, is not any natural form of this substance, but is a very elegant preparation obtained from one or other of the above-named rocks by more or less direct chemical processes. The older process was a somewhat tedious one, consisting of careful calcination and washing of a mixture of potash alum and ammonia alum; the product being a very light form of alumina of rather inconvenient bulk, this was mostly used by ceramic colour-makers.

Owing to the recent invention of a method of electrical extraction of metallic aluminium—or, as the Americans say, aluminum, from alumina—more economical commercial means for the preparation of alumina on the large

scale have been devised; and alumina has thus become an ordinary article of commerce, more easily obtainable and in denser and more manageable condition than formerly, and possibly of a higher degree of purity.

The processes of alum manufacture from pyritous shales and from clays in the old way is fully described in many technical manuals, and therefore need not be repeated here.

When prepared from cryolite, "The mineral is first dried and then reduced to a fine powder, and intimately mixed with powdered limestone. This mixture is then calcined, in which process the fluorine unites with calcium to form calcium fluoride, which is insoluble in water, while the sodium and aluminum are oxidized and form probably a soluble aluminate of sodium and a carbonate of sodium. By leaching with hot water, the aluminate of sodium and the carbonate of sodium are removed. Carbon dioxide gas is forced into the tanks containing these solutions . . . . and the aluminum is precipitated as aluminum hydroxide, and the sodium forms sodium carbonate. . . . . The aluminum hydroxide precipitate is washed to free it from traces of sodium carbonate, and, after drying, it is either sold in this rough form, or it is manufactured into sulphate of aluminum or alum." (*Mineral Resources of U.S.A., 1903*, p. 884.)

But probably the greater quantity of alumina is prepared from bauxite, a natural compound of the hydrates of alumina and iron, more or less impure. The principal sources of this rock or mineral are: Beaux near Arles, in the south of France, where some 50,000 to 60,000 tons per year are raised; Georgia, Alabama, and Arkansas, in the United States, where over 20,000 tons are raised; and County Antrim, in the north of Ireland, where, according to *The Mines and Quarries Report*, 10,191 tons of bauxite were raised in the year 1901.

The bauxite or alum-clay of Co. Antrim, Ulster, occurs in seams laying between sheets of Tertiary basalt. It is conveyed from the mines to Larne Harbour, and there the pure alumina is prepared from the mineral, at the works of the British Aluminium Co., who ship the alumina thence to Foyers in Inverness-shire, for electrical extraction of the metal.

Messrs. Bowes & Sims, analytical chemists, of Blackley, Manchester, have very kindly described the manufacture of hydrate of alumina at Larne as follows:—"The process now in work at Larne Harbour for the production of hydrate of alumina was invented by C. J. Bayer. E.P. 10,093, 1887, and E.P. 5296, 1892. The raw material is bauxite, from County Antrim, with an average of 56 per cent. alumina, 3 per cent. ferric oxide, 12 per cent. silica, 3 per cent. titanic acid, and 26 per cent. of water.

"The ore is crushed to $\frac{1}{4}$-inch cubes, and then calcined to burn off the organic matter.

"It is then cooled and re-crushed, so that it will pass through a 30-mesh

sieve. The finely crushed ore is then treated in pressure kiers with caustic soda solution of 1·45 sp. gr. at a pressure of 70 to 80 lbs., for two or three hours, until decomposition is complete.

"The liquid is then run off, water added to reduce the sp. gr. to 1·23, and the solution of aluminate of soda so obtained freed from precipitated oxide of iron by filter-presses, and precipitated by hydrate of alumina, in the cold, whilst constantly agitating the liquid, this precipitation continues until the ratio between the molecules of alumina and soda is one to six, when it stops.

"The hydrate of alumina is then allowed to settle, and filter-pressed by means of compressed air. The weak liquor from the pressed cake of hydrate of alumina is concentrated in multiple evaporators to the sp. gr. of 1·45, and then used to attack fresh quantities of bauxite."

Properties.—Sp. gr., 3·9 (Roscoe), 4·2 (Shaw). Chemical symbol, Al_2O_3. Commercially two distinct forms of alumina are offered, viz.: alumina hydrate, containing 50 per cent. Al_2O_3; and calcined alumina, practically 100 per cent. Al_2O_3. It is therefore of greatest importance to ceramists to be quite clear as to which form is specified in the recipes, and which is used.

This ingredient has proved of greatest possible service in the satisfactory preparation of leadless glazes for maturing at low temperatures, by reason of its peculiar property of preventing or retarding opaline tendencies.

Professor Binns—referring indeed to all glazes whether containing lead-compounds or not, and in respect of alumina in the form of silicate rather than pure—has remarked that "In addition to the bases and acids, it has been found necessary to introduce certain components which occupy a neutral position, but which nevertheless exercise an important influence upon the glaze. Foremost amongst these stands alumina, without which it seems impossible to construct a satisfactory glaze, and it has been found that ferric oxide exerts a similar power. The office of these substances is that they prevent injury to the glaze by prolonged and repeated firing, and greatly assist the perfect adjustment of glaze to body." (*Ceramic Technology*, pp. 72, 73.)

For further notes on the properties of alumina, see Chapter XI.

Boracic Acid.—Two terms are in use in connection with this ingredient, viz., boracic acid and boric acid. It will be well to make some distinction between them at the outset, perhaps, so as to avoid misunderstanding. Boracic acid, a derivative from borax, should properly be applied to the commercial article with its usual impurities; while the term boric acid may be more properly confined to the acid in a state of chemical purity.

From Roscoe we learn that, in 1774, "Höfer, a Florentine apothecary, observed the occurrence of this compound in the water of the lagoons of Monte Rotondo in Tuscany, and in 1815 a manufactory was erected on the spot for

the purpose of obtaining boric acid from the water." (*Treatise on Chemistry*, vol. i. p. 543, Macmillan.)

For many years the principal sources of boracic acid were the volcanic districts of Tuscany and the Lipari Islands, one of which—Stromboli—is still an active volcano. To these sources must now be added numerous districts upon the Pacific coast of America, and several inland lacustrine deposits of minerals containing borates.

In Tuscany water is embasined round natural jets of hot vapour, which rise up from small fissures in the earth's surface. The water is supposed to percolate to strata containing borates, and to be subsequently ejected by the upward movement of the intermittent vaporous jets, in a condition more or less impregnated with boron compounds. Series of these receptacles are formed, and saturation is effected by conducting the impregnated water from one to another of the embasined jets: when the waters are sufficiently saturated with salts of boron, they are run into tanks and evaporated until crystallization takes place. (See Roscoe and Schorlemmer's *Treatise on Chemistry*.)

These crystals are conveyed to the port of Leghorn, and thence exported in the form of yellowish-white, glistening, scale-like crystals, containing about 82 per cent. boric acid, 2½ per cent. moisture, and 15 per cent. of impurities, such as sulphates of ammonia and magnesia, with traces of lime, soda, potash, silica, and iron. According to Muspratt, from A.D. 1818 to A.D. 1828 1,500,000 lbs. of this boracic acid were exported from Italy; and after A.D. 1828 the export was 2,600,000 lbs. per annum, thanks to Count Larderel's resource and enterprise.

Preparation.—The United States report for 1901 describes the treatment of the marsh deposits of sodium borate in Harney County, Oregon, thus:—"The ground is level and treeless, and is incrusted with a layer of sodium borate several inches in thickness, which contains also sodium carbonate, sodium sulphate, sodium chloride, and other salts. During the summer the loose surface deposit is shoveled into small heaps and is replaced by a second incrustation within a comparatively short time. . . . The crude mineral, containing from 5 to 20 per cent. of boric acid, is shoveled into tanks of boiling water, and chlorine or sulphuric acid is added to decompose the alkali salts, and thus free the boric acid. After twenty-four hours the clear supernatant liquor is drawn off into crystallizing tanks and cooled, yielding white pearly scales of high-grade boric acid and a mother-liquor." (*Mineral Resources, U.S.A., 1901*, p. 871.)

Refined boracic acid may be prepared either by recrystallizing the crude Italian or American acid, or by precipitating boracic acid crystals from solutions of borax by chemical means; the precipitated crystals being collected, washed with water, redissolved by boiling in water, and then allowed

to crystallize out. These highly refined crystals are then collected and dried. (See *Pottery Gazette*, May 1899, p. 569.)

Properties.—Sp. gr., 1·43 to 1·48. Chemical symbol of boric acid crystals, $B_2O_3,3H_2O$, or HBO_2H_2O, or H_3BO_4. Chemical composition, 56·5 B_2O_3, 43·5 H_2O.

Loss on fusion in a frit-composition of the crude Italian boracic acid, about 52½ per cent., and of the refined boracic acid, 45 per cent.; but this loss is independent of any that may under certain conditions take place by volatilization of the boric anhydride itself.

Boric acid is soluble in hot alcohol, forming a rather volatile ethyl borate. Glassy boric oxide is almost non-volatile, and requires very high temperatures to dissipate it in vapour. (*Pottery Gazette*, May 1899.)

Respecting the physiological action of boric acid, much conflicting evidence has been published on account of its use as a food-preservative. Dr. Alfred Hill referred to it in an address to the Sanitary Congress, 1898; and a letter appeared in the *Birmingham Daily Post* of 14th October 1898, from the Federated Grocers' Association, controverting Dr. Hill's assertions.

A long article upon this matter also appeared in the *Lancet* on 7th January 1899.

For an extended consideration of the use and influence of boric acid in ceramic glazes, see Chapter XI. of this volume.

Borax; Tincal.—Borax or borech, according to Rutley, is a term of Persian origin, whilst tincal is supposed to be the Indian or Dutch term. Tincal, formerly, was almost exclusively obtained from Thibet, where incrustations on the borders of certain lakes were periodically dug up, and thence transported to Calcutta, whence it was exported to Europe. At some point in its course it was covered by a protective film of saponaceous character, to retard the escape of water of crystallization, and consequent effervescence and loss. From a remote period, Muspratt tells us, borax has been refined in the seaport towns, more particularly in Venice; whence the appellation Venetian borax applied to the purified salt. At a later period the purification was also conducted in Holland, whence for some time England derived supplies. Dr. Ure, whose *Dictionary of Chemistry* was published in 1820, states that "Borax was for a long time unknown in Europe. In 1772 a certain Mr. Abrahamson sent some to Sweden, just as it was dug out in Thibet, where it was known as pounnxa, mypoun, and honipoun.

Shaw, in his *Chemistry of Pottery*, published in 1837, writes:—"This compound, found native in different parts of the East Indies and South America, has long been an article of commerce as tincal, and considerable quantities are consumed weekly for glazes"; but in his list of inventors of ingredients that have proved specially influential in the advancement of ceramics, he omits to mention who introduced borax.

We find no mention of boracic acid or borates either in the Delft or the Rouen recipes; nor do they appear in Frye's patents for glazes used at Bow A.D. 1744 and 1749; nor yet in Cookworthy's glazes patented 1768, or Champion's of 1775. Neither do these ingredients appear in recipes purporting to be old Worcester formulæ, during the second period, *i.e.*, 1776 to 1783. It is worth noting that Josiah Wedgwood died in 1795, yet no reference to tincal or borax occurs in any memoirs of his remarkable life with which we are acquainted; and Mr. Cecil Wedgwood confesses his absence of definite information as to whether his renowned ancestor ever used these substances or not.

Dr. Aitken's description of the manufacture of earthenware in Staffordshire in 1795–1796 gives the composition of the glaze then in use as 60 lbs. white-lead, 10 lbs. flint, 20 lbs. Cornwall stone, and this corresponds to recipes attributed to Josiah Wedgwood. (*Pottinge in ye Oldene Tymes*, p. 19, Harper.)

By a patent, dated 3rd October 1796, granted to Ralph Wedgwood, in respect of a "newly discovered and invented composition for making glass upon new principles," we learn that borax formed part of the claim. And in Hickling's patent, 28th February 1799, for vitreous enamels for lining iron culinary vessels, borax is again mentioned. These are the earliest notices of its use in connection with our subject we have been able to trace.

It is a matter of history that Nantgarw pottery was founded in 1813, and was partially pulled down and the manufacture completely changed in 1823. Now, it is noteworthy that borax appears in recipes purporting to be those of Nantgarw. Then, again, we find borax an important ingredient in the leadless glaze invented by Mr. John Rose, of Coalport, and for which the Society of Arts gold medal was awarded in 1820. Borax is also frequently mentioned in the manuscript recipes of James Furnival, which would be in practical use in Staffordshire from about 1817 to 1840.

Brongniart was probably correct in dating its practical introduction in English glazes A.D. 1800; but, according to Muspratt, the price of borax made from tincal was three shillings to four shillings per lb. in France in the year 1815; so that not until a later date would it be very largely used.

Count Larderel's ingenious improvements and economies in the treatment of the products of Tuscany were effected in 1828, and from this date borax was more largely used; but, at first, borax made in England from Tuscany boracic acid and soda was not well received by British potters—they didn't like its appearance; and, according to the *Pottery Gazette* of May 1899, p. 568, the borax was sent from England to Amsterdam, and from thence to France and England as Dutch borax, before it could be sold.

By 1854 Brongniart assumed that of the estimated total of 1500 tons of borax used annually throughout the entire world, 1000 tons were used in

Great Britain, Staffordshire alone taking 666 tons per annum. (*Traité des Arts Céramiques*, tom. i. p. 608.) But this apparently did not include the supply of tincal obtained direct from India.

The modern sources of borax are perhaps most concisely shown by the tabulated statistics of the world's production of borates during recent years, as given in metric tons in the report of the United States Geological Survey on the *Mineral Resources of the United States for 1901*, p. 872, thus:—

Year.	United States. Calcium Borate.	Chile. Calcium Borate. Exports.	India. Borax. Exports	Germany. Boracite.	Italy. Boric Acid, Crude.	Peru. Calcium Borate. Exports.	Turkey. Pandermite. Exports.
1896	12,310	7,486	340	184	2,616	1,179	12,626
1897	17,600	3,168	280	198	2,704	11,850	11,375
1898	13,911	7,034	184	230	2,650	7,178	not reported
1899	21,834	14,951	not reported	183	2,674	7,638	not reported
1900	23,456	13,177	,,	232	2,491	7,080	not reported

"There was a slight decrease in the production of borax in the United States during 1901, the output being 17,887 short tons of crude borax, valued at $314,811, and 5344 short tons of refined borax, valued at $697,307. . . . . Of the output in 1901, California produced 16,887 short tons of crude borax valued at $297,198, and the total quantity of refined borax. The production of borax in the United States continues to be derived mainly from the colemanite deposits of California, although a small quantity is produced from the marsh deposits of California, Nevada, and Oregon."

After giving some details of the operations in California and Oregon, the report continues with notes on the production of other countries, as follows:—

"*Argentina.*—The International Borax Co. operated the Tres Moros Mines during 1901, employing five hundred laborers, and produced on the average 700 tons per month. The shipments from the province of Salta to Europe during the year exceeded 16,000 tons.

"*Chile.*—Borax and boracite are found principally in the districts of Aocotan and Carcota, province of Antofagasta, although other deposits occur in the department of Copaipo, province of Antacama. The deposits of Ascotan and Carcota, which were worked for a long time by a Chilean company, are now under the control of a Californian company. During 1900 these mines produced 13,176 metric tons of calcined boracite and 26 metric tons of borax. . . . .

"*Russia.*—Borax is found in the Kertch and Taman Peninsulas of Southern

Russia, where it occurs in connection with mud volcanoes. Soon after eruption the mud becomes incrusted with various salts, including borax, soda, and salt, which are recovered by dissolving in water and subsequent evaporation.

"*Turkey.*—The mineral borocalcite, a calcium borate, in Asia Minor, furnishes the base for the manufacture of the greater part of the borax supply of Europe." (*Min. Res. U.S.*, *1901.*)

Bulletin No. 55 of the U.S. Geological Survey contains the following chemical analyses, which we have tabulated and condensed for ready reference:—

a. Colemanite, from Death Valley, California ; large transparent crystal, perfectly clear.
b. Do., but in form of a deposit implanted on gangue, consisting of small blade-like crystals, almost white, in some lights of a greenish cast.
c. Pricite, from Curry County, Oregon ; white and chalky.
d. Pandermite, from the Island of Panderma, in the Black Sea ; hard and compact, somewhat resembling marble.
e. Ulexite, from Rhodes' Marsh, Esmeralda County, Nevada.
f. Ludwigite, from Morawitza, Banat, Hungary.
g. Datolite, from Bergen Hill, New Jersey ; transparent white crystals.
h. Dauburite, from Russell, St. Lawrence County, New York ; pink, lustrous.
i. Axinite, from Cornwall ; clove-brown colour, translucent, implanted on quartz.
j. Axinite, from Bourg d'Oisans, Dauphiny, France ; pearl-gray color, and in some smaller crystals almost colourless and quite transparent.
k. Tourmaline, massive black, easily fusible ; from Auburn (Me.).

	a.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*	*h.*	*i.*	*j.*	*k.*
H_2O,	21·87	22·66	22·75	19·40	29·46	3·62	6·14	...	1·80	2·16	4·18
B_2O_3,	50·70	49·56	47·04	48·63	43·20	12·04	22·60	25·80	4·64	4·62	10·55
CaO,	27·31	27·36	29·96	32·16	14·52	...	35·14	23·26	20·53	21·66	0·49
MgO,	0·10	0·25	...	...	...	30·57	...	...	0·66	0·74	0·04
SiO_2,	...	0·44	...	...	0·04	...	35·74	49·70	42·10	41·53	37·85
NaCl,	...	...		...	...	...	...	...	...	...	...
Fe_2O_3,	...	...		...	...	37·93	...		3·06	3·90	0·42
FeO,	...	...	0·25	...	...	15·78	0·31	1·02	5·84	4·02	3·88
Al_2O_3,	...	...		...	...	...	...		17·40	17·90	37·73
Na_2O,	...	...	...	...	10·20	...	...	...	...	...	2·16
K_2O,	...	..	...	...	0·44	...	...	...	...	...	0·62
Cl,	...	...	...	...	2·38	...	...	...	...	...	...
SO_3,	...	...	...	...	0·28	...	...	...	...	...	...
MnO,	...	...	...	...	...	0·16	...	...	4·63	3·79	0·51
P_2O_5,	...	...	...	...	...	...	...	...	...	...	trace
Li_2O,	...	...	...	...	...	.	...	...	...	...	1·34
F,	...	...	...	...	...	...	...	...	...	...	0·62

Bulletin No. 200 of the United States Geological Survey, entitled *Reconnaissance of the Borax Deposits of Death Valley and Mohave Desert*, by M. R. Campbell, supplies the following interesting facts:—"Originally borax was obtained by evaporating the waters of Clear Lake, about eighty miles north of San Francisco, where it was first produced on a commercial scale in 1864.

. . . . The industry flourished at this and other lakes in California, until in the early seventies borax in large quantity, and in a very pure condition, was discovered on many of the alkaline marshes of Western Nevada and Eastern California. Refining plants were established in the vicinity of Columbus, Nev., and at several points in California, the most important of the latter being in San Bernardino County, at Searles's Marsh, west of the Slate Range, in Inyo County, near Resting Springs, and at the mouth of Furnace Creek, in Death Valley. These plants flourished for a time . . . . but the increased production of borax in this country, together with the importation of large amounts from Italy, so reduced the price that in a few years most of the plants were abandoned.

"About 1890 it was found that the borax crust on most of the marshes is a secondary deposit, being derived from the leaching of beds of borate of lime in the Tertiary lake-sediments that abound in the region. This discovery revolutionized the borax industry, for the bedded deposits are much more extensive, are more easily accessible, and are in a purer condition than the marsh-crusts. The marshes were abandoned, and a mine was established on a bedded deposit at Borate, twelve miles north-east of Daggett, San Bernardino County, Cal. At the present time this plant, owned by the Pacific Coast Borax Company, is the chief producer of borax and boracic acid in this country. The value of this deposit led to extensive prospecting in various parts of the territory, and to the discovery in Death Valley of enormous deposits that far excel those now being worked near Daggett. The borax of Death Valley, as well as that near Daggett, occurs in a regular stratum, inter-bedded with semi-indurated sands and clays that make up the bulk of the strata. These beds are generally regarded as of Tertiary age, and they are supposed to have been deposited in inclosed bodies of water. Since the bedded deposits of borax always occur in association with strata of this character, it is probable that careful study and search will reveal deposits of this nature in localities other than Death Valley and Daggett."

Death Valley is said to be fifty miles long by about five or ten miles wide, and the lowest point of its floor is supposed to be about 480 feet below sea-level. It is not only the lowest point in the surface of the United States, but is also regarded as the hottest place in the country. The summer temperature is reported to reach 137° in the shade. Its sinister name is said to have arisen from the fact that in 1849 a band of emigrants wandered into the valley, and most of them perished from thirst before an avenue of escape was discovered. Mohave Desert and the Death Valley region are desolate in the extreme. The mineral found is borate of lime or colemanite, and occurs in a bedded deposit from 5 to 30 feet thick; but although the colemanite is interbedded with the sand and clay, it is not co-extensive with these strata. As a trace-able bed it probably extends for a distance of a mile and a half, but beyond

this limit it is very thin, and in many places it is wanting in the section. At the Borate Mine there are two outcrops of colemanite.

Respecting Furnace Creek, the Bulletin proceeds:—"By far the greatest exposure of lake-beds, and also the largest deposits of borax that are known, occur in Funeral Mountain, or, as they are more generally described, on Furnace Creek in Death Valley. These sediments lie diagonally across Funeral Mountain, in a belt whose reported width is twelve or fifteen miles. On the north they are limited by an abrupt mountain wall of paleozoic limestones, shales, and quartzites, which stand from 3000 to 4000 feet above the general level of the Tertiary hills on the south. . . . .

"The lake-sediments of this region are similar to those previously described. . . . . Interbedded with the rocks of this series is a bed of colemanite (borate of lime), which, though probably not continuous, shows in outcrop in a number of places across the mountain, a distance of at least twenty-five miles. This constitutes the largest deposit known in this country, and presumably the largest in the world. The bed has been opened low in the foothills on the east side of the mountain, four or five miles south of the Ash Meadows Road. At this point the bed is visible for several hundred yards, and in the prospect pits it has a thickness of from 4 to 10 feet. . . . . The bed is composed of a mass of crystalline colemanite, which mines readily and with little waste. . . . . According to Superintendent Roach, of the Pacific Coast Borax Company, the largest mineral deposit occurs about nine miles up Furnace Creek, on a nearly direct line between the outcrops just described. At this point he reports a bed of boracite 60 feet in thickness." (Bulletin 200, U.S. Geol. Survey.)

Another interesting description of the Borate districts of California appears in vol. v. of *Trans. Am. Cer. Soc.* in the form of a photographically illustrated lecture by Dr. Edward Hart, of Easton (Pa.), entitled "Death Valley, California, and its Borax Industry." In the course of this he refers to the forest of petrified tree-trunks at Adamana, about one thousand acres in extent, of which he humorously remarked that, "While silica is one of the materials of the potter, it does not seem likely that we will ever be making commercial ware out of petrified trees."

He also mentioned immense deposits, containing nitrate of soda, on hills surrounding Morrison's Ranch, Willow Creek, on Amaragosa River.

He notes that out of the eighteen thousand tons of borax used in the United States in 1901, seventeen thousand tons came from Daggett.

Preparation.—Dr. Hart explains that "At Marion the Pacific Borax Co. has built a mill for roasting the colemanite. Colemanite is a borate of lime, containing water. On roasting, it loses the water and falls to a fine powder, which can be sifted out. The valueless mud mixed with some of the colemanite does not fall to a powder when heated, and in this way the

colemanite is purified. The fine powder is put in sacks and sent to Bayonne (N.J.), where it is treated with sulfuric acid, which combines with the lime. The boric acid goes into solution in the hot water, which is poured off, and as this cools the boric acid crystallizes out. The boric acid is then sold as such for enamelling iron, for pottery, for glassmaking, etc.; or it is boiled with carbonate of soda, and so converted into borax. The colemanite treated at Marion comes from Borate, twelve miles to the north-west of Daggett."

With regard to that treated at Daggett, Dr. Hart writes:—"This country is full of boric acid, which seems to have accumulated in the ancient lake which once covered all this country, and has since completely dried up. At one place, seven miles north-west of Daggett, an old lake-deposit, 60 to 90 feet thick, is found standing now almost vertically. It is a hardened mud, and was originally deposited as such on the old lake-floor. It contains 10 per cent. of boric acid, and is worked at Daggett, where it is mixed with water, treated with sulfur dioxid, made by burning sulfur, and the solution allowed to evaporate in shallow tanks. No artificial heat is needed; the sun does the evaporating at a tremendous rate. This is easily understood. The temperature reaches 118 in the shade, and there are frequent winds with a velocity of forty miles and more an hour." (*Trans. Am. Cer. Soc.*, vol. v. p. 68.)

The United States report already mentioned describes the treatment of the mineral borocalcite of Asia Minor, which is said to furnish the base for the manufacture of the greater part of the borax supply of Europe, as follows:—

"The crude mineral is treated with caustic soda, forming borax and calcium carbonate, although the best results are obtained by using a mixture of caustic soda and sodium bicarbonate. The ore is finely crushed in a mill, and fifteen parts of mineral are placed in a steam-heated boiler with sixty parts water, eight parts sodium bicarbonate, and two parts caustic soda, the whole being boiled for about three hours. The resultant liquor is filtered, and the hot filtrate yields at the end of several days crystals of borax, which are steam-dried, assorted, and barrelled. The cake of calcium carbonate remaining in the filter-press is washed with water until the borax content is completely extracted, and is then sold to glass, paper, and cement works. It is estimated that 100 lbs. of borocalcite will yield from 100 to 105 lbs. of borax crystals." (*Mineral Resources of the United States, 1901*, p. 872.)

English refined borax, *i.e.*, the prismatic form of borax containing ten molecules of water of crystallization, is, according to the *Pottery Gazette* of 1st May 1899, p. 567, prepared as follows:—"A solution of crystallised carbonate of soda is made in a lead-lined vat, which is heated by steam from a boiler, the quantity of steam required being regulated by a valve. The pipe conveying the steam into the vat is pierced with a multitude of small holes,

through which the steam escapes into the solution. . . . . When the carbonate of soda is dissolved and the temperature has reached 212° Fahr., boracic acid is added in small proportions at a time, so that the effervescence which occurs may not cause the liquid to overflow the sides of the dissolving vat. When all the acid which is required has been added, the vat is covered up, and the temperature raised to 219° to 221° Fahr., and a gravity of 32° to 33° of Twaddell's hydrometer (attained). If the solution be too weak, a sufficient quantity of crude borax is generally added; if the reverse, boiling water is added. The liquid is now allowed to stand twelve hours, during which time the heat is kept up by using a closed coil (*i.e.*, not pierced), through which steam is passed. The clear solution is then drawn off into wooden lead-lined crystallisers. When the crystallisation is complete, the mother-liquors are drawn into a cast-iron receiver. . . . . The crystals are removed and drained on an inclined plane. . . . . The usual charge is 26 cwts. of carbonate of soda, dissolved in about 330 gallons of water. To saturate this 24 cwts. of crude boracic acid are required. The crystallisation generally requires from two to three days. . . . . The crude borax of the first operation is redissolved in a large lead-lined vat, which has a capacity of 18,000 lbs. of borax, with the water required for its solution. The heat required is obtained by steam from a boiler, which is conveyed through an open steam-coil. The borax is placed in an iron basket, which is suspended by a chain, and allowed to sink just below the surface of the liquid in the vat. . . . . The basket is refilled as fast as the borax dissolves, until the whole charge has been added. To each cwt. of borax 17·63 lbs. of crystallised carbonate of soda are added, to saturate any excess of boracic acid, after which the solution is brought up to a temperature of 212° Fahr. At this heat the solution should have a density of 34° Twaddell (sp. gr., 1·169); if not, it must be brought up by the addition of more crude borax, or reduced with boiling water, as the case may be. The solution is then drawn off into the crystalliser, which has the capacity to receive the entire contents of the boiling-vat. The crystallisation must be slow, to insure large and perfect crystals of borax. To this end the crystallising-vat must be kept warm by covering closely, and sometimes by surrounding it with spent tan-bark or straw mats. In twenty-five to thirty days the temperature has become reduced to 77° to 86° Fahr., when the mother-liquor is drawn off, the crystals broken down, and removed by the aid of hammer and chisel. The result is the ordinary prismatic borax of commerce." (*Pottery Gazette*, 1st May 1899, p. 568.)

But special methods are sometimes adopted, according to the materials employed; for instance, under certain circumstances sulphate of soda is used in place of carbonate.

Properties.—Sp. gr., 1·71. Chem. symbol, $Na_2B_4O_7 + 10H_2O$, or it may be written $Na_2O,2B_2O_3 + 10H_2O$. Chemical composition: boric acid, 36·65;

soda, 16·23; water, 47·12 (Royle). Loss on calcination or fusion in a frit-composition about 47 per cent. When heated the crystals swell up, losing their water of crystallization, and forming a snow-like spongy mass, called calcined borax. This, upon continuing the heat to fusion-point, collapses and melts into a transparent mass, called glass of borax, which possesses a sp. gr. 2·367 (Roscoe). This glassy borax is readily soluble in water, but insoluble in alcohol (Roscoe); it is liable to become opalescent, and to effloresce upon exposure to air. As a general rule, when borax is used in ceramic glazes or enamels a preliminary fusion of the borax with a portion of the other ingredients is effected; and in case of large quantities this is accomplished in a special reverberatory furnace called a frit kiln. By this means the composition, called "frit," is brought into an approximately homogeneous condition. When melted, the frit is allowed to flow out of the furnace into a tank of water, where it cools, solidifies, and becomes more or less shattered into pulverizable fragments.

The power of borax in dissolving colourant metallic oxides is well known, and its delightful facility of fusion renders it one of the most elementary reagents of a chemical laboratory. These properties all show themselves when borax is used in glazes, and in addition it imparts brilliance and a water-white transparency unattainable by any other ordinary ceramic materials. To this remarkable transparency and whiteness must be attributed its rapid success as a competitor with lead compounds for use in glazes. For further notes on borax, see Chapter XI.

Physiologically, its action, as observed by Royle, is referred to thus:—"Borax has no specific action on the system; it is eliminated by the kidneys unchanged; it is antacid, detergent, and destructive of fungi." (*Materia Medica*, p. 158.)

Now, silk being an animal product, may justly be brought into discussion here. Of this, Mr. G. H. Hurst, in his work on *Silk Dyeing*, informs us that hydrochloric acid solutions dissolve silk in the cold; that alkalies dissolve silk, and even limewater attacks silk; but he says "Borax has no action on silk." (*Silk Dyeing*, p. 9.)

On the other hand, a long article appeared in the *Lancet* of 7th January 1899, in which ill effects resulting from its internal administration are mentioned.

Whenever soda sulphate has been used in any way in the manufacture, there is the possibility of extremely minute contamination by arsenic; how near or how remote we are quite unable to indicate.

Common Salt.—In Great Britain common salt is principally obtained from thick beds of rock-salt in the Keuper marls of the triassic series; Cheshire, Staffordshire, Durham, Lancashire, Worcestershire, and Yorkshire being the counties where it is raised, the two former supplying the greater

portion of the total output. During the year 1901 Cheshire and Staffordshire together raised 1,169,755 tons, out of an aggregate of 1,783,056 tons.

The Cheshire deposit consists of two beds—the first, at a depth at Northwich of 120 feet below the surface, is about 75 feet thick; it was discovered in 1670 during boring for coal: the second or lower bed is about 225 feet below the surface, and from 90 to 120 feet thick; these two vast deposits being separated vertically by about 30 feet of marl, and the whole covering an area of about sixteen miles by ten miles. (See Roscoe, W. J. Harrison, etc.)

And with regard to the Droitwich salt-beds, the mines there are said to have yielded revenues to Worcester Cathedral for a thousand years. (See *Geology of the Counties*, p. 296.)

In the United States of America many bore-holes have been put down. and rock-salt discovered at a depth in some cases of as much as 2500 feet, At Tully, in New York State, a bed of rock-salt has been discovered at a spot some 400 feet above the level of the saltworks at Syracuse (N.Y.). Higher still several lakes exist, and water from these lakes is conducted to the rock-salt beds at Tully, which are some 1800 feet below the surface, and the head of water is sufficient to lift the brine to reservoirs on the surface, whence it flows by gravitation to the works at Syracuse (N.Y.). (See lecture by T. Ward, 14th December 1894, *Jour. Soc. Arts.*)

One salt-field is said to exist in the middle of the Colorado Desert, a little to the north of the Mexican border, and 264 feet below the level of the sea. This has been described as "a field of crystallised salt, more than a thousand acres in extent, presenting a surface as white as snow; and beneath the noonday glare of the sun so dazzling that the naked eye cannot stand its radiance, it stretches away for miles about Salton (Col.), an ocean of blazing, blistering white." (*Stone Weekly News*, 26th September 1902.)

Salt is produced in a number of the states, the most important being New York, Michigan, Kansas, and Ohio, which together yield 85 per cent. of the whole output of the United States.

In Canada there are very extensive deposits of common salt, and brine-springs are met with around the shores of Lake Winnipegosis in Manitoba; in the Mackenzie River basin, north of Athabasca Lake; and brine is raised at Wingham and Exeter, Huron Co., and at Windsor, Essex Co., Ontario. From the catalogues of Canadian Mineral Exhibits at Glasgow (Scotland), 1901, and at Buffalo, N.Y. (U.S.A.), 1901, we glean the following:—

"The real salt industry of Canada is located in Ontario, some ten or fifteen firms operating at various points in the counties bordering the south-eastern shores of Lake Huron, and along the St. Clair and Detroit Rivers, from Kincardine to Windsor. The mineral is produced by pan-evaporation of brines, pumped from wells drilled to the underlying salt-beds of the

Onondaga rocks, which are of Upper Silurian age. From a boring made by Mr. Attrill at Goderich in 1876, to the depth of 1517 feet, with a diamond-drill, the existence of six beds of rock-salt has been ascertained as follows:—(1) 30 feet thick, 1027 feet from surface; (2) 25 feet thick, 1085 feet from surface; (3) 34 feet thick, 1127 feet from surface; (4) 15 feet thick, 1223 feet from surface; (5) 12 feet thick, 1243 feet from surface; (6) 6 feet thick, and 1385 feet from surface.

"These salts are not all alike in purity. The first is scarcely suitable for mining, while the second is remarkably pure; the third approaches it in this respect. The latter two beds, which together measure over 60 feet, are separated from each other by a layer of less than 7 feet of rock, and for practical purposes may be regarded as one great workable mass.

"Dr. Hunt, who analysed the salt, calculated that the yield from the best white layer, which is 10½ feet thick, would be 880,000 bushels to the acre.

"The Windsor Salt Co. is the largest salt-producer in Canada. The first well was sunk in 1892. . . . . In 1896 another boring was sunk, which reached a depth of 1672 feet, proving the existence of four salt-beds, which aggregate a thickness of 392 feet, the lowest, which is the thickest, being alone 250 feet."

A very interesting description of a visit to an Austrian salt-mine, by Mrs. E. Brewer, appeared in the *Leisure Hour* of 1886, p. 560. After describing the preparatory changes of dress for the descent, she continues:—

"I followed close behind; then came the second and younger guide, and my husband brought up the rear. In this order we walked till my guide paused before a low iron door in the side of the mountain, when, before unlocking it, he lighted his lantern, the others doing the same, and bade us observe strictly any orders he gave while in the mine. He unlocked the door, and, as soon as we had passed through, relocked it behind us. Outside the heat had been intense; inside the air seemed actually frozen, so great was the contrast. We found ourselves in a long passage lined with planks. . . . . Along this we went without a word till we had left the planking behind us, and the passage seemed hewn out of solid black rock, interspersed here and there with white marble. . . . . It was all mineral salt, and the taste of it was salt, but not at all bitter.

"The silent walk through this low, narrow passage . . . . lasted about twenty minutes. . . . . The end of it, however, brought us to the first *shaft*, a word which until now had had no meaning for me. It was a deep, black hole; how deep it was impossible to guess. From the platform where we stood there ran two sliding-poles, evidently running from the top to the bottom, wherever that might be. On the right of these poles a strong rope was attached, and running the whole length from top to bottom The

directions to us were clear and imperative. The conductor placed himself outside the two poles, and put his right foot under the rope, grasping it also with his right hand. I came next, doing exactly as he had done, except that instead of grasping the rope I put both my hands on his shoulder; behind me came the second guide, and lastly my husband. When we had fallen into position, my guide began to move, at first slowly, down into this dark abyss, lighted only by the three candles carried by my companions. . . . As soon as he saw we were obeying instructions, and had our nerves under control, he increased the rapidity of the movement till we went like the wind. The descent may not have lasted above a couple of minutes, I cannot say; it is impossible to reckon time or, indeed, think of anything at such moments. . . . . We went down four or five such shafts, till at length I felt an intense pleasure in the performance. At the bottom of the second shaft we came to a chamber containing many instruments or tools, which had been dug up at various times by the miners, and which, as our guide said, proved beyond a doubt that salt had been dug out there before the Christian era. . . . As we were descending the last shaft, a deep rumbling noise disturbed the deathlike silence, and as the door was closed behind us we were deafened and surrounded by the noise of rushing waters. Courageous as I thought myself, I felt a choking sensation in my throat which only tears could have removed. 'Tell me,' I said to the guide in a quiet voice, 'are we in danger; has some accident occurred in the mine?' . . . 'No, lady,' said my giant kindly, 'nothing is wrong. It is the rushing of a large body of water through the mine, but it is held in strong bounds.' . . . To give me time to recover, he told us that we were 1380 feet below the point at which we entered the mine. We again moved onward through the passage to the tune of the rushing waters, until a door impeded our further progress. This our guide unfastened with one of the many keys on his girdle, and we found ourselves in a square space, just large enough to permit our standing. Fastening the door through which we had passed, he unlocked another which stood opposite. How can I tell you what we saw?—a sight so unexpected, so different to anything we ever had seen. . . . We found ourselves standing on the shores of a black lake, a silence as of death pervading the whole. At the landing beneath our feet was moored a large barge, in which sat an old man silently awaiting us. Around the lake, which was very large, hundreds of little oil-lamps of every hue were sending out their bright lights. We were breathless. Surely we were at the Stygian Lake, and there sat Charon, awaiting the golden bough from Sibyl before ferrying us over. In a silence which might be felt we stepped into the boat one by one, and the guide stamping twice with his foot, the boat glided to the opposite shore, where we got out and passed through a door, which was locked behind us. Here we paused to give expression to our delight, and our thanks for the way in which we were

being made acquainted with the wonderful scenes of this lower world. . . . . We had not yet done with the shafts, but went down two or three more, till we found ourselves 660 feet below the lake over which we had been ferried.

"Here another surprise awaited us. We were in a very narrow, low-vaulted passage, laid with rails. . . . . In the far distance a single star shone upon us. How could it be shining under the earth, we did not pause to consider: there it certainly was. . . . . A sign was given, and we went at a quick pace for some few minutes, when the whole conveyance made a sudden pause. 'Look,' said the guide, 'and see how we are drawing near to the star.' Doing so, we found it to be daylight peeping in and no star at all. We were off again in the same rapid style, and there were no more stoppages until we found ourselves at the bottom of the Dürnberg, not five minutes' walk from the town. Here in a chamber we found attendants with our dresses, and after distributing a few coins to all who had been instrumental in giving us so much pleasure, we bade them good-bye, and in a short time found ourselves out in the warm sunshine making our way back to the inn. . . . . At the end of the meal my guide appeared to say that the superintendent would gladly show us over the saltworks if we desired it. We went at once, and had the satisfaction of seeing the whole process of purifying, evaporating, and drying. We learned also the way in which the factory was supplied with dissolved salt from those lakes across one of which we had been ferried. On our return to Salzburg we had one of the most glorious sunsets . . . . and thus ended a day which had been full of interest. . . . ."—EMMA BREWER. (*Leisure Hour*, 1886, p. 561, R.T.S.)

Along the shores of the Mediterranean, the Atlantic shores of Spain, Portugal, and France, and shores of the Red Sea and Indian Ocean, Mr. Ward states there are many places where "solar" salt is made; that is, salt prepared by the heat of the sun's rays. Mr. Ward continues:—"The numerous salt lakes on the Russian steppes produce immense quantities of solar salt, as also does Lake Sambhur in Central India. In the Dead Sea and along the eastern shores of the Caspian Sea, where there are both heat and dryness, salt is deposited very largely. . . . . One of the most interesting deposits of solar salt is that in the Kara Boghaz Gulf, on the east coast of the Caspian Sea. . . . . So great is the evaporation over this extensive body of water that it is estimated by the best authorities that at least three hundred and fifty thousand tons of salt are being deposited daily, and an enormous bed of rock-salt is being formed on the bottom of the gulf." (*Jour. Soc. Arts*, 14th December 1894.)

E. H. Parker, Esq., of Liverpool, devotes a chapter to the question of salt-producing and salt revenue collecting in China in his book on China. He writes:—"We have the valley of the Canton River, the old region of the northern Yüeh kingdoms, the old kingdoms of Wu and Ch'u, all supplied with

sea-salt extracted and prepared in different ways, according to the natural facilities at hand. . . . . Then we have the various kinds of well-salt, which supply the western and mountainous parts of China, broadly corresponding to the ancient kingdoms of Shuh, Tien, and K'ien. The lake-salt of the desert competes with the pond-salt of Shan-Si for the service of what may roughly be styled the mixed Tartar-Chinese regions. Finally, there are the primitive reed-flats of the North, which serve the needs of the greater part of old China." (*China: her History, Diplomacy, and Commerce*, p. 209, Murray.)

Preparation.—Rock-salt is often more or less impure; only about 15 feet in thickness of the lower bed at Northwich is mined, the other being more economically raised in the state of brine—a solution of salt in water from 3 to 26 per cent. strong. Where no natural springs exist, and insufficient rainfall to supply the water to the rock-salt beds, fresh water is introduced by means of bore-holes, and after dissolving its quota of salt is pumped up as brine. Hence preparation is partly a process of purification which takes place often at considerable depths below the surface. The subsequent treatment of the brine is merely a question of economical and carefully regulated evaporation and crystallization.

The processes are varied according to the particular circumstances of the deposit or source, and the particular kind of crystal of salt required. Mr. Ward even mentions that in cold regions salt is obtained by freezing the brine, with the disadvantage of producing three tons of ice at the same time for every ton of salt.

But the common method is evaporation by heat and dry air, or occasionally, recently, assisted by vacuum. The heat may, of course, be either natural or artificial—solar heat being cheapest; but as the latter cannot be controlled effectively, it is necessary to use artificial heat for the production of particular qualities. Any fuel may be used; wood was formerly used even in England, but now mostly the finest and worst of slack (coal-dust) is used, being generally the cheapest artificial heating substance obtainable.

Mr. Ward states that until brine contains about 26 per cent. salt, no crystalline salt is formed, because "salt in brine is not held in suspension, but in solution," and "however long the brine is allowed to remain, say in a closed vessel, no salt will deposit." (*Jour. Soc. Arts*, 14th December 1894.)

Mr. Ward continues:—"Hence, before any salt can be made, the water must be reduced so as to leave the proportion of seventy-six water to twenty-four salt. . . . In artificial brines, or such natural ones as are found on beds of rock-salt, the proportion of water to salt is usually three to one, to commence with; so that it does not take long before there is sufficient evaporation to cause the salt to form or crystallise out of the brine. Brine boils at 226° Fahr.; but it is not necessary to heat it to this point before evaporation commences and salt forms. The whole business of saltmaking consists

. . . . in using the proper amount of heat to produce the kind of salt wanted. The greater the heat, the more rapid the evaporation, and the finer the grain of the salt. The lesser the heat, the slower the evaporation, and the coarser the grain of the salt. The fine or boiled salt is taken frequently out of the pan, the coarse less frequently, according to the degree of coarseness wanted." (*Jour. Soc. Arts*, 14th December 1894.)

Mr. Ward describes the preparation of solar salt on the sea-shore, and on the shores of the great Russian and Indian salt lakes; and concludes with a minute description of the manufacture of the several kinds of white salt produced in England, viz., butter salt, common (or broad) salt, fishery salt, bay salt, handed squares stoved salt (lump-salt, such as is seen on hawkers' carts), etc.

For salt-glazing purposes the only kinds we need refer to are common or broad salt and fishery or curing salt; the former made at from 170° Fahr. to 190° Fahr., in long pans and with a most economical use of fuel. As much as two and a quarter tons of salt is obtained from saturated brine at the expense of one ton of fuel.

When common salt is required fine it is taken out of the pans every twenty-four hours; if coarser, as ordinary common salt, every two days; and if specially coarse, at intervals of three days. Fishery salt is a coarse solid-grained salt, nearly approaching solar salt, produced at a lower temperature than common salt, and allowed to remain longer in the pan, so that the crystals may grow larger or "feed." Sometimes a little alum is put in the pans, to cause more solid grains to form, the salt being taken out of the pans about every five or seven days, best fishery or best Scotch fishery salt being taken out at intervals of fourteen days or even more. ("The Manufacture of Salt," by Thomas Ward, *Jour. Soc. Arts*, 14th December 1894.)

Properties.—Sp. gr., 2·16. Chemical symbol, $NaCl$. Common commercial impurities, sulphate of lime, sulphate of soda, and chloride of magnesia, all usually in small proportion.

Roscoe and Schorlemmer, in their *Treatise on Chemistry*, state that "Sodium chloride melts at 776° (Carnelley) and crystallizes on cooling. It begins to volatilize at temperatures not far removed from its melting-point, and hence cannot be fused without loss (Stas). When heated with silicic or boric acid, sodium chloride is decomposed, with liberation of hydrochloric acid and formation of a silicate or borate." (*Treatise on Chemistry*, vol. ii. part i. p. 113.)

Its behaviour in salt-glazing will be referred to in Chapter XI.

In the discussion following Mr. Ward's paper, Mr. F. W. Price inquired what was the effect of salt-working upon the health of the men engaged in it. In reply, the lecturer stated that "The trade was extremely healthy. The men lived long, and seemed to enjoy their lives very much. Certainly it had not been perceived that their health was affected in the least, whether they

were engaged down below or in the works above-ground, though they no doubt were in a damp atmosphere." (*Jour. Soc. Arts*, 14th December 1894.)

Soda-Ash.—The old method of making soda-ash was to decompose common salt by means of sulphuric acid, in large iron pans, covered so that the vast volumes of gaseous hydrochloric acid evolved could be collected and dissolved in water. The residual cake of soda sulphate was afterwards withdrawn, crushed, mixed with finely pulverized limestone and coal, and the mixture heated in a slowly revolving drum-shaped furnace for two hours, then drawn out and cooled.

This crude product, called "black ash," was then broken up and lixiviated, soluble soda carbonate being washed out. The solution was next treated so as to carbonate any caustic soda there might be, and was afterwards boiled down to crystallization point, the crystals allowed to form, then withdrawn and drained and calcined, the product being the *Leblanc* soda-ash of commerce, invented A.D. 1792.

More recently, however, the foregoing process has been largely superseded by Solvay's ammonia method, worked by Messrs. Brunner, Mond, & Co., of Northwich. The process is described by Roscoe and Schorlemmer thus:—"It is termed the ammonia soda process, and is now being carried out on the large scale, both in England and on the Continent. It depends on the well-known fact that when carbon dioxide is passed into a solution of common salt in aqueous ammonia a double decomposition occurs, and the slightly soluble bicarbonate of soda is precipitated—

$$NH_3 + CO_2 + NaCl + H_2O = HNaCO_3 + NH_4Cl.$$

The mother-liquors, containing sal ammoniac, are heated with lime or magnesia, and thus the ammonia is regained for subsequent use." (*Treatise on Chemistry*, vol. ii. p. 152, Macmillan.)

From this precipitated bicarbonate of soda the soda-ash of commerce is prepared thus:—The damp bicarbonate of soda is heated in an iron pan to recover the carbonic acid and any remaining ammonia, decomposition taking place according to the equation—

$$2NaHCO_3 = Na_2CO_3 + CO_2 + H_2O.$$

There are two kinds of 58 per cent. soda-ash, light and heavy. The heavy quality is prepared by refurnacing and partially fusing the light, the preparation of which has just been described.

Properties.—Chemical symbol, Na_2CO_3. Chemical composition, 58·5 per cent. Na_2O, 41·5 per cent. CO_2; an average chemical analyses of Brunner, Mond, & Co.'s pure alkali showing 99·22 per cent. carbonate of soda. The loss on calcination in combination with silica, etc., in a frit kiln is probably 42 per cent.

Soda-ash is soluble in water, and effervesces violently with acids, CO_2 being

evolved. It forms an easily fusible silicate, and will dissolve flints if boiled together in water and under pressure, in this manner forming water-glass or soluble silicate of soda. When the proportion of silica is high and fusion effected by heat in a furnace, a less soluble compound results, but still easily attacked by CO_2 gas.

Soda was an important ingredient in Egyptian, Roman, and Venetian glass, and is still in French and English crown, window, and plate glass. But in the hard Bohemian glass its place is taken by potash.

It is used by ceramists chiefly in the preparation of glaze-frits, sometimes in conjunction with boracic acid, and sometimes in lesser quantities in conjunction with borax, its effect being in the latter case to cheapen the cost of glaze and to modify the effect of the glazes upon underglaze colours.

Soda Crystals.—In the preparation of soda crystals, the soda-ash of commerce is taken and dissolved in water, and carefully recrystallized under conditions that induce the formation of large masses of crystals, containing ten molecules of water.

Properties.—Sp. gr., 1·45. Chemical symbol, $Na_2CO_3 + 10H_2O$. Chemical composition, 21·6 Na_2O, 15·3 CO_2, 62·9 H_2O.

Upon analysis, Brunner, Mond, & Co.'s soda crystals yield :—

Carbonate of soda,	37·1
Sulphate of soda,	0·4
Chloride of soda,	0·3
Water,	62·2

The loss upon simple heating, then, may be about 63 per cent., and the loss upon calcination and fusion with silica, etc., in a frit is about 78 per cent. For this reason this ingredient is not very satisfactory for making frits, except as a means of promoting amalgamation; the evolution of 62 per cent. water and 15 per cent. carbonic acid would probably make an appreciable difference in time of fritting and cost of fuel. These crystals are soluble in water, effervesce violently with acids, and are liable to effloresce in the atmosphere, forming monohydrated carbonate of soda.

Phosphate of Soda.—Mr. G. H. Hurst has very kindly described the commercial method of preparation of this ingredient for me thus :—"Bone-ash is finely ground and treated with strong sulphuric acid. This converts the calcium phosphate in the ash into soluble acid phosphate. The acid liquor is drawn off from the insoluble calcium sulphate, diluted with water, and then soda added until the liquor is neutralised and effervescence ceases. The precipitated carbonate of lime is allowed to settle, the clear liquor boiled down, and the phosphate of soda allowed to crystallize out."

Royle states that when heated to 302° the salt is obtained in the anhydrous condition (Na_2HPO_4), a hard white mass.

Properties.—Sp. gr., 1·58. Chem. symbol, $HNa_2PO_4, 12H_2O$. Chem. comp.,

17·32 Na_2O, 19·84 P_2O_5, 62·84 H_2O (Hurst). Hence the loss on fusion in a frit is probably about 64 per cent.

This compound is occasionally used by ceramists as an ingredient of turquoise, and in blue enamels from cobalt; but its physiological action being definite, and as some pyrophosphates, when introduced directly into the blood, are found to be very powerful poisons (Gamgee), this substance is perhaps better avoided as far as possible.

Further, in his investigations into the presence of arsenic in beer and food, William Thomson, F.R.S. Edin., F.I.C., found three grains of arsenic per lb. in a sample of phosphate of soda. (*Jour. Soc. Arts*, 15.2.1901, p. 203.) This most likely got in by means of the sulphuric acid used in its manufacture; it is, nevertheless, a point to remember.

Nitre.—Roscoe and Schorlemmer, in their *Treatise on Chemistry*, give an interesting description of the sources of nitre, from which the following particulars are mostly obtained:—"Saltpetre occurs together with other nitrates as an efflorescence on the soil in various hot countries, especially in Bengal. The formation of nitre, whether found in the soil or in porous felspathic rocks, is due to the gradual oxidation by the air of nitrogenous organic matter in contact with an alkali. In the decay of such bodies, ammonia is first formed, and the nitric acid subsequently produced." This, combining with the potash salts, forms an efflorescence of nitre. This is collected, and, by repeated solution and recrystallization, is converted into purified nitre.

But "since the discovery of potassium chloride at Stassfurt, this salt has been largely used for the artificial manufacture of saltpetre. This manufacture depends upon the fact that, under certain conditions of temperature and pressure, solutions of Chili saltpetre (sodium nitrate) and of potassium chloride undergo, when mixed, a double decomposition, chloride of sodium being deposited, and potassium nitrate remaining in solution. . . . . The clear solution on cooling and on agitation deposits the saltpetre in the form of flour."

Properties.—Sp. gr., 2·07. Chem. symbol, KNO_3. Chemical composition, 46·54 K_2O, 53·46 N_2O_5. The loss on fusion in a frit or flux, when the whole of the nitric anhydride is dispersed, will be about 54 per cent.; but if by any means the nitre is simply converted into potassium nitrite, then the loss will be comparatively small. Its use by potters for oxidizing purposes arises from the fact that, upon heating, nitre parts with a portion of its oxygen, forming potassium nitrite, KNO_2. Respecting the physiological action of nitre, Royle observes that "In poisonous doses (1 to 1½ oz. retained and only slightly diluted) nitre causes violent gastric and intestinal inflammation, attended by pain, vomiting, and purging, followed by collapse. It is therefore an irritant. In medicinal doses it is readily absorbed into the blood, and, according to Dr. Stevens, when given freely it renders the venous blood, even in the last

stage of fever, scarlet, and retards or prevents its coagulation. . . . . It has been largely employed in rheumatic fever, and with good effects." (*Materia Medica.*)

Pearlash.—Potash compounds are widely distributed in nature among the felspars, the granitic rocks, nearly all soils, and in sea water. It may even be extracted from sheeps'-wool washings; but the chief commercial source of potash, until recently, was and possibly still is *vegetation.* Potash salts are found in nearly every living plant. Disintegration of felspathic rocks causes soils to be impregnated with potash salts in a more or less soluble condition, and these are taken up by plants during growth. Hence, when wood, bark, stems, seeds, or stubble are burnt, the ashes are found to contain impure potash carbonate.

By lixiviation the soluble salts are washed out of the ashes, and the solution on evaporation yields a residue of crude potashes. This crude product is heated in a reverberatory furnace and gaseous and carbonaceous impurities driven off, the remaining salt forming the pearlash of commerce.

Properties.—American pearlash may contain 66 per cent. K_2O, 26 per cent. CO_2, 7 per cent. K_2SO_4, with traces of KCl and insoluble matter; but Royle remarks:—"For commercial purposes it is extremely necessary to *ascertain* the quantity of alkali contained in any specimen of commercial potash."

As sulphates are sometimes deleterious in ceramic compositions, the presence of 7 per cent. K_2SO_4 should be remembered by users. The loss on fusion in a siliceous mixture will probably be 31 per cent. Prior to the general introduction of borax about 1830, pearlash was a much more essential ingredient to ceramists, and more often found in their recipes. Its ceramic uses now are perhaps chiefly confined to the making of smalts, flint-glass, Bohemian glass, parian frits, enamel fluxes, and Persian glazes stained by manganese, together with occasional use in the making of some of the green and pink colours.

Magnesia.—The principal commercial source of magnesia now is dolomite or magnesian limestone. From this, sulphate of magnesia is first prepared by one of two methods:—(*a*) By simply saturating dilute sulphuric acid with the powdered stone, and separating the soluble magnesia sulphate from the insoluble calcic sulphate. Or (*b*) the dolomite is roasted to expel carbonic acid gas, then slaked and largely washed with water to remove part of the lime, then mixed with sulphuric acid, and the mixed calcic and magnesia sulphates separated by crystallization.

From the sulphates thus obtained, carbonate of magnesia is prepared by dissolving ten parts of sulphate of magnesia and twelve parts of carbonate of soda in water, and evaporating the mixture to dryness; then digesting the residue in water, decanting the fluid, and collecting the insoluble matter on a calico filter; this residue being afterwards repeatedly washed with water: the

dried residue being carbonate of magnesia, a pure white impalpable powder, nearly insoluble in water.

Calcined magnesia (MgO) may be prepared from the carbonate by exposing it to a low red heat in a loosely covered crucible until the CO_2 has been driven off and the powder causes no effervescence with sulphuric acid. (See Royle's *Materia Medica.*)

Zinc Oxide.—The sources of zinc are the ores blende and calamine, the former a native sulphide, the latter a native but impure carbonate of zinc. These are found mostly in Great Britain, Belgium, and America. From mines situated in the British Isles, during the year 1901, there were raised 23,752 tons, equivalent to 8418 tons of zinc-metal: the chief contributories being Cumberland, 7350 tons of zinc-ore; Northumberland, 2816 tons; Wales, 10,549 tons; Isle of Man, 1897 tons. The single mines raising over 2000 tons of ore during 1901 were Nenthead, Alston, Cumberland, 6722 tons; Carshields, West Allendale, Northumberland, 2816 tons; Minera, Wrexham, Denbighshire, 3490 tons.

From these ores zinc-metal is first prepared. Owing to its volatile nature it is estimated that 15 to 24 per cent. of the metal present is lost in the process of smelting.

White oxide of zinc may be prepared by the combustion of metallic zinc, or by the action of heat on the carbonate or the hydroxide of zinc.

The combustion process is described by G. H. Hurst in his work on *Painters' Colours*, and from that source the following summary is taken:—Retorts are placed in suitable furnaces, and therein are raised to a white heat, then ingots of zinc-metal are thrown into the retorts: all apertures are now closed, excepting those leading from the air to the combustion-chamber, and into the collecting-chamber. The zinc soon begins to volatilize, and, on issuing from the mouth of the retort, burns. The zinc-white formed by the combustion of the vapour is of two kinds, light and heavy: the former passes into the chambers, and is there collected; the latter drops down the combustion-chamber, being rather heavy, into a barrel placed for its reception, and, being usually of poor colour, may be returned to the retorts with the next batch, along with a small quantity of carbon in some form or other. The zinc-white made by this process is very white.

Properties.—Sp. gr., 5·6. Chemical symbol, ZnO. Chemical composition, 80·25 Zn, 19·75 O. From its chemical composition no loss would be anticipated upon calcination in a frit or colour, but personal experience casts doubt upon this notion, for sometimes loss of weight apparently takes place. White oxide of zinc is a gritty bluish-white powder, which, when heated alone, turns yellow while hot, becoming white again on cooling. It is reputed to be insoluble in water, oil, alcohol, or turpentine, but soluble in most acids without effervescence. Common adulterants are barytes, china-clay, whitening,

and possibly *terra alba*; these should be tested for when such a course seems desirable. In glazes, zinc oxide is disposed to cause opalinity, and should therefore be used very cautiously for that purpose. Physiologically, its effect is possibly injurious, because chloride of zinc is such a powerful caustic.

White Oxide of Tin.—Without considering the somewhat numerous foreign localities whence tin-ores are now derived, it will suffice to say that tin-ores have been raised from Cornish mines almost continuously since the time of the Phœnicians, 1440 B.C. In A.D. 1872 no less than *£1,459,990* value of tin was raised in Devon and Cornwall alone, but since then the output has shrunk, until in 1901 the value was *£458,559*, almost all from Cornwall.

Preparation.—Block-tin is first obtained by smelting the tin-ores; this block-tin is then heated in an iron ladle, and poured into cold water, so as to form grain-tin; that is, metallic tin in a granular condition. Or block-tin may be melted and then stirred up with whitening, which after a time effects the fine subdivision of the metal. From this granulated or grain tin the white oxide may be prepared by one of the following methods:—

(1) By carefully treating the tin with nitric acid, when violent oxidation occurs, a hydrated white powder resulting, which yields the dioxide upon washing and ignition. (Roscoe.)

(2) By mixing 2 lbs. of grain-tin with ½ lb. nitric acid and 10 ozs. of water, and calcining in a potter's glost oven, allowing free access of air during calcination.

(3) By mixing 2½ lbs. granulated tin with 4 oz. nitre, and firing on biscuit plates in the glost oven.

(4) By spreading granulated tin about 2 inches thick on dishes, and upon the tin spread one-fifth its weight of nitre, then cover up, but so as to admit air; calcine in a potter's oven; wash and dry.

Properties.—Sp. gr., 6·71. Chem. symbol, SnO_2. Chem. composition, 78·38 Sn., 21·62 O. The loss on calcination in a frit or flux when an oxidizing atmosphere is maintained, practically *nil*; but in a reducing atmosphere, or in association with reductive elements, a loss may take place.

Insoluble in water. No effervescence with dilute acids. When melted in fluxes, usually remains as an opaque, yellowish-white, uncombined component. Possesses the remarkable property of yielding pink or crimson colours when calcined in mixtures with whitening, and a trace of chrome oxide. And not less remarkable, possibly, is it that many enamels containing a high percentage of tin oxide, when applied directly upon ceramic bodies, will curl off in the burning, unless the body contains a very considerable proportion of lime carbonate, as in the case of Delft ware, Rouen ware, and Italian mediæval faience.

Iron Compounds.—Those principally used in the decorative-tile trade are ochre, hematite, carbonate of iron, calcined ironstone, "bull-dog," iron scales, Crocus Martis, red oxide of iron, and Japanese red.

Ochre is the native hydrated oxide of iron, of various shades of yellow and yellow-brown, often more or less associated with clay and sand. In England it occurs in beds, mostly about one foot thick; principally in Somersetshire, Gloucestershire, Devonshire, Wales, and Derbyshire. Formerly ochre was raised in Oxfordshire, but apparently little is got there now. A not inconsiderable quantity of ochre is got from deposits of ochreous streams in or exuding from mines. Large quantities of ochre are also obtained from Avoca in Ireland, and from France and Spain.

Hematite, or red ironstone, is the native ferric oxide in an anhydrous condition, sometimes associated with carbonate of lime. It has been largely mined in Cumberland, Lancashire, and near Froghall, in Staffordshire; the two former counties raising over two million tons during 1897. Small quantities of special colourant power are found in the Forest of Dean (Gloucestershire), and enormous deposits are said to occur in the Isle of Elba.

Dr. Angus Smith's analysis of Froghall hematite was as under:—

Peroxide of iron,	68·61
Silica,	5·49
Carbonate of lime,	18·17
Carbonate of magnesia,	3·72
Manganese, alumina, and moisture,	4·00

Red hematite is one of the principal iron-ores of the United States. In 1901 it contributed over twenty-four million tons, or 83 per cent. of the total output, the greater part being supplied from Lake Superior region.

Carbonate of Iron.—Impure carbonate of iron occurs in great quantities in the lias formations of North Yorkshire, known as the Cleveland district, some five million tons a year being raised.

I am indebted to E. H. Cooke, Esq., of the Cleveland Steel Works, for the following analyses of this mineral:—

CLEVELAND CLAY-BAND IRONSTONE.	
Protoxide of iron,	35·64
Peroxide of iron,	3·00
Protox. manganese,	0·73
Alumina,	7·85
Lime,	5·50
Magnesia,	4·50
Silica,	9·53
Phosphoric acid,	1·03
Carbonic acid,	21·00
Sulphur,	0·13
Organic matter,	2·00
Moisture,	9·00
	99·91

CALCINED CLEVELAND IRON-ORE.	
Peroxide of iron,	58·80
Peroxide of manganese,	1·00
Alumina,	10·75
Lime,	8·03
Magnesia,	6·66
Silica,	13·09
Sulphur,	0·18
Phosphoric acid,	1·41
	99·92

Occasionally, particularly in glazes, a much purer carbonate of iron is used, either artificially prepared, or the native chalybite or siderite. This latter occurs in Cornwall, Devon, Somerset, and Cumberland, and, according to Rutley, contains 60 per cent. iron, 36 per cent. carbonic acid, and a little manganese, lime, and magnesia.

Calcined Ironstone.—The ground material sold under the name of common ground ironstone is probably "mine riddlings" from the ironstone heaps so frequently seen in Staffordshire. This ironstone, a carbonaceous earthy carbonate of iron, known as Black Band stone, occurs in the coal-measures.

By the courtesy of Messrs. Robert Heath & Son, I am able to append an analysis of the "mine" or calcined ironstone at their Burslem Grange Mines:—

Oxide of iron,	82·75
Silica,	3·55
Lime,	3·45
Magnesia,	1·49
Alumina,	0·89
Phosphoric acid,	1·65
Sulphuric acid,	0·75
Oxide of manganese,	3·50

The riddlings probably would not be quite so pure.

Calcined iron oxide may also be obtained from acid works, where gasworks sulphurated bog-iron oxide from the purifiers has been roasted.

"*Bull-Dog*" is a waste product from iron puddling furnaces; it is black in colour, or almost so, and extremely dense and hard. It is supposed to be an impure silicate of iron. It is serviceable in compounding bodies for black and silver-grey flooring tiles, and will maintain its black colour very persistently; hence, when finely ground, it becomes a useful ingredient.

Iron Scales.—These are the shingles from iron forge mills which flake off the iron during rolling. The only preparation consists of washing and grinding. It is occasionally used in glazes, and in U.G. and enamel colours.

Crocus Martis.—This is an old-fashioned term, probably derived from the alchymists, who denominated iron, Mars. Hence ferrous sulphate or green vitriol was called *Sal Martis*; tartrate of iron, *tartrated tincture of Mars*; and magnetic or black oxide of iron, *Æthiops Martialis.* (See Ure's *Dictionary of Chemistry*, p. 556, and Royle's *Materia Medica*, pp. 199–209.) Crocus essentially denotes the saffron colour of the hydrated peroxide of iron. Ure states that the yellow or saffron coloured oxides of iron and copper were formerly called Crocus Martis and Crocus Veneris, and that that of iron is still called crocus simply by the workers in metal.

But the article now usually found in commerce under the name of "Crocus Martis" is not yellow or saffron coloured, but purplish red, such as the writer believes was formerly called "colcothar." Probably this has arisen from the preparation and use of calcined hydrated oxide of iron, *i.e.*, calcined Crocus

Martis, and the prefix gradually falling out of use, as in the case of flint; hence the "Crocus Martis" or red crocus-powder of to-day, both of which are apparently inappropriate or self-contradictory terms for the substances to which they are now applied. Red crocus-powder has been defined as follows:—"A polishing powder prepared from crystals of sulphate of iron, calcined in crucibles. It is really the calcined powder taken from the bottom of the crucible, where the heat is most intense. The powder in the upper part is called 'jewellers' rouge,' but the crocus-powder is of a purple-red colour, is harder, and is used for ordinary work; whereas the rouge is of a scarlet colour, and is only used for gold and silver work." (Law's *Grocers' Manual*, p. 593.)

Royle uses "Crocus Martis" as a synonym for ferric oxide or red oxide of iron, and in all probability the best qualities of what is now commercially known as Crocus Martis are, in fact, particularly pure and elegant forms of ferric oxide. Nevertheless, Crocus Martis is a somewhat indefinite term,[1] and may be applied to either hydrated ferric oxide, ochres, calcined ochres, calcined wastes or bye-products from copper extraction works, acid works, or gasworks, or to the pure and beautiful product above described, resulting from the calcination of ferrous sulphate (green vitriol; copperas).

Red Oxide of Iron.—In addition to the native red oxide (hematite), there are several chemically prepared varieties. These are mostly obtained by calcining sulphate of iron, or some salt of iron that happens to be a bye-product of some other manufacture, until it assumes the brightest attainable shade of red. The purest qualities of these artificially prepared red oxides of iron are very reliable, and useful staining oxides for making coloured glazes where accuracy of effect is important.

Japanese Red is probably only a commercial name for the ochreous stone, otherwise known as "*Grès de Thiviers*," although of this the writer is not absolutely certain. From the *Pottery Gazette*, June 1901, we learn that the chemical analysis of *grès de Thiviers* is as follows:—Silica, 87·3; ferric oxide, 8·5; moisture, 1·9; lime, 0·87; undetermined, 1·43. But analysis does not yet appear to have revealed the whole secret of the pretty shade of salmon-pink obtainable by means of the material commercially known as Japanese red or Persian red. Its behaviour rather suggests the presence of some subtle force similar to that exercised by the minute trace of chromium in the pink colours; and observation leads to the conclusion that it contains some element that is inclined to cause crazing. The "*undetermined*" matter may contain this often-sought yet still unrecognized element.

Blue from Iron.—From Muspratt we learn that "Gmelin has proved by chemical experiments that it is not only possible to give glass and enamel a blue colour by means of iron, but that several of the antiquities, upon which

[1] Langenbeck mentions inferior "Crocus Martis" which was found to contain ferric oxid, 47·14; alumina, 2·31; silica, 13·65; barium sulfate, 37·41.

so much stress has been laid, afford not the slightest indication of cobalt. . . . . He mentioned . . . . several articles on which a blue color is produced by the vitrification of iron . . . . in particular, those slags found near the smelting mines in the Hartz Forest, some of which are of a beautiful blue colour. . . . ." (Muspratt's *Chemistry*, p. 481, vol. i.)

Manganese Compounds.—The ores and oxides of manganese form another important series of tile-colourants. Comparatively inferior manganese ores occur in Great Britain in the counties of Derby, Cornwall, Devon, Warwick, and Merioneth; but richer ores are now imported in large quantities from Germany, Chili, India, Turkey, Russia, Spain, France, Portugal, Greece, Japan, and Brazil. The insignificance of the home product will be better understood by reference to the *Mines Statistics*. In 1897 only 599 tons were raised in the United Kingdom, whereas 156,324 tons were imported.

Umbers are somewhat variable, impure, hydrated native oxides of iron and manganese, usually clove-brown colour and dull, earthy, meagre feel. When calcined they should be brownish black. Sometimes these are used in brown, black, and chocolate coloured bodies.

Wad, another ore of manganese, is a soft disintegrated kind, very like soot in appearance, and usually composed of 30 per cent. protoxide and 60 per cent. sesquioxide of manganese. It probably results from the decomposition of harder ore. This is a valuable ore, and perhaps rather extensively used by tilemakers.

Pyrolusite, the native binoxide of manganese, contains from 80 to 95 per cent. of MnO_2 associated with other oxides of manganese and variable quantities of iron oxide, alumina, lime, and silica. Its colour is iron-black or steel-grey, often very hard. When this is used it is usually finely levigated in wet-grinding potters' mills.

Carbonate of Manganese.—Sometimes this is obtained as a native ore (dialogite) from mines near Oswestry and Barmouth; but most of the carbonate of manganese now used by ceramists probably is the bye-product from bleaching-powder works. It serves a useful purpose for glaze-staining.

Black Oxide of Manganese, or recovered manganese, is a chemically prepared, very elegant product of manganese, recovered as a bye-product from the manufacture of bleach by the Weldon process; the carbonate so formed, and referred to above, is simply roasted until all carbonic acid is expelled. It comes into the market in such a fine state of division and degree of purity that have secured for it a very wide application for staining glazes.

At times it may contain an excessive proportion of calcium compounds, and these must be guarded against.

Manganese has long been used as a ceramic material; the violet of the ancient Egyptian and the mediæval Persian tilemakers probably contained manganese. To attain this tint it seems that purity is not by any means the only essential condition, and it is remarkable that the treatment that yields celeste tints

with copper oxide as a colourant, yield violet when manganese forms the colourant. Boracic acid appears to be injurious to this tint, hence the best results are obtained by use of special glazes.

Cobalt.—The ores of cobalt are :—*Arsenical cobalt*, containing about 74 per cent. arsenic, 20 per cent. cobalt, and from 3 to 6 per cent. of iron and copper. *Cobalt glance*, containing about 49 per cent. arsenic, 35 per cent. cobalt, 7 to 20 per cent. sulphur, and 3 to 6 per cent. iron. *Cobalt pyrites*, containing about 43 per cent. cobalt, 38 per cent. sulphur, 5 to 14 per cent. copper, and 3 to 5 per cent. iron.

For many years only small and tentative supplies appear to have been obtained from British mines in Cornwall, Flintshire, Cumberland, and Scotland ; and since 1890 the output, according to statistics, has been *nil*. The Chinese mines, also, are understood to be now either exhausted or little worked.

The principal commercial sources at the present time are, apparently, Schneeberg (Saxony), the Erzgebirge (Bohemia), Modum (Norway), Tunaberg (Sweden), Missouri (U.S.A.), New Caledonia, and the Transvaal.

In the United States a high-grade cobalt-ore deposit is being developed, it is said, in the eastern part of Oregon ; otherwise the only nickel and cobalt produced in the United States during 1901 were as bye-products from the smelting of lead-ores at Mine la Motte, Missouri. The matte, containing the nickel and cobalt, was refined at Constable Hook and Camden (N.J.), and there were obtained 6700 lbs. of nickel and 13,360 lbs. of cobalt oxide. This is the highest production of cobalt oxide in the United States since 1897, when 19,520 lbs. were reported. But beside this home product of 13,360 lbs. of cobalt oxide in the year 1901, the United States imported 71,969 lbs. in the same year. These figures are also the highest recorded import, far in excess of former years ; and thus denote an increasing consumption of this oxide in the States.

Considerable quantities of cobalt oxide are obtained by extraction of small percentages found in the residues remaining after treatment of ores of nickel and copper. When its use and the means of its extraction were first discovered, it is said that one firm of Birmingham nickel refiners found itself the fortunate possessor of waste slags worth £7000 on account of its cobalt contents. In 1851 Henry Hussey Vivian, who had found cobalt and nickel present in slags and inferior metals separated out during the process of smelting copper-ores, patented an improved method for separating nickel and cobalt, or either of them, in the form of arsenides from ores, slags, or regulus, and other combinations or alloys of copper. For full description of this process, see Muspratt's *Chemistry*, p. 490.

Zaffre, or Saffre.—Judging by the writings of the various authors consulted, this substance may be of uncertain composition. Roscoe refers to it as an impure cobalt arsenate resulting from the calcination in air of cobalt ores ; Cunynghame says it contains about half its bulk of black oxide ;

Muspratt seems to confuse it with certain qualities of smalts; whilst Hermann gives the following circumstantial description of its preparation:—"The ores are first freed from gangue, and, in case they contain bismuth, must be refined to get rid of the latter. They are then stamped in the dry state and roasted in a calcining furnace, where they are stirred continually with iron poles. In this process arsenic escapes as white oxide, and is collected in the arsenic chimney in connection with the furnace. On removal from the furnace the ore is sifted and the large lumps returned to the stamping-mill. This oxide is, by reason of the arsenic and iron present, either reddish or bluish green in colour, and is known as zaffre. It is now mixed with fine sand or crushed quartz (two or three parts), moistened a little, and packed in barrels for sale under the above-mentioned name." (*Painting on Glass and Porcelain*, p. 53, Scott, Greenwood, & Co.)

Smalts.—This is a double silicate of cobalt and potash; and though probably not much used by ceramists of our time, an outline of the process of manufacture may not be without interest. Hermann describes it somewhat as follows:—"Cobalt ore is roasted in such a manner that the cobalt is mainly in the condition of protoxide; the other metals not being oxidised, but chiefly separable as arsenides in the subsequent smelting process. The roasted ore is then fused with potash and silica, producing a cobaltous oxide potash glass. By pouring this glass into cold water it is obtained as a brittle mass, which is then stamped to a fine powder, and subjected to a very tedious process of sedimentation." The proportions given by Muspratt are, for some qualities, 2½ cwts. of ordinary roasted ore, 2 cwts. of roasted mixed ore and cobaltiferous quartz, 20 cwts. of sand, 3½ cwts. of eschel (a faintly coloured glass produced by washing the smalts), and 10 cwts. of potash. For smalts marked ME, MC, FC, the mixture given is 2 cwts. of best roasted ore, 5 cwts. sand, 2 cwts. eschel, 4 cwts. potassa.

The purity of the sand is of great importance, for any colourant oxides such as iron, manganese, copper, or nickel would injure the tint of the smalts.

It is also found desirable to exclude lime and soda, and to exercise great vigilance regarding the purity of the potash used.

It is interesting to note that, although the ancients knew how to colour glass blue with slags containing cobalt, and even modern colour-makers also from 1540 A.D., when smalt was invented in Saxony, yet not until 1733–1735 was it discovered (by Brandt) that the blue colour did not depend on the iron and arsenic in the slags as was supposed, but upon some peculiar metal hitherto unisolated to which he gave the name of *Kobalt-rex*.

Refined Cobalt.—An old Staffordshire method of refining cobalt was as follows:—60 lbs. cobalt ore, 50 lbs. potash, 25 lbs. sand, 10 lbs. charcoal are pounded and intimately mixed together, then put into small crucibles, about 1½ lbs. in each, and fired for about eight or ten hours; commencing with a

slow fire, and then increasing until the whole is melted. Obtain the intermediate regulus as in the zaffre process, then to every 50 lbs. of regulus add 6 lbs. potash; pound and thoroughly mix them, then put it into bottles (earthenware), each containing about 1 lb. of the mixture; recalcine as before, and repeat this process until the scoria is of a bluish hue and bright (generally necessary to do so three or four times). The next process of "roasting" the refined regulus is to separate the arsenic from the oxide of cobalt. Spread a layer of the pounded refined regulus, half an inch thick, upon a flinted biscuit dish, apply a gentle heat for a few hours, not enough to fuse the regulus, but just to drive off the arsenic.

Blue Calx is then prepared in the following manner:—30 lbs. of refined regulus of cobalt from the foregoing process is pounded and intimately mixed with 1 lb. of plaster of Paris and ½ lb. borax, and the mixture placed in earthenware biscuit cups (1½ inch high, 3 inches diameter, ½-inch thick), each cup being filled almost full. These are then fired in a kiln with as brisk a fire as possible until the mixture is in a melting state; continue the heat for about six hours, and then cool the kiln quickly. This process occupies twelve or thirteen hours; the blue will then be found at the top of the cups, and the nickel at the bottom. The nickel can be recalcined to recover any more cobalt it may contain.

According to Llewellyn Jewitt, W. Cookworthy, the discoverer of Cornish china-clay, was the first chemist in England who succeeded in making a good cobalt blue direct from the ore; before his time the colour was prepared by grinding imported foreign zaffres. (*Life of Wedgwood*, p. 232.)

Black Oxide of Cobalt.—According to Muspratt, "In the preparation of the oxide on a large scale, the ores are smelted, and the regulus or speiss which they yield calcined. The resulting product is then dissolved in strong hydrochloric acid, and the iron and arsenic precipitated by the gradual addition of milk of lime. When the oxides have subsided, the clear supernatant liquor is run off, and subjected in vats to a stream of sulphide of hydrogen. . . . . When the sulphides have completely settled, the supernatant liquor is siphoned off, and the cobalt precipitated from it by bleaching-powder. The hydrated oxide thus obtained, heated to redness, constitutes the blue oxide; and to whiteness, the prepared oxide of commerce." (Muspratt's *Chemistry*, vol. i. p. 483.)

Brongniart's description of Evans and Askin's process fills up a few little details that are wanting in Muspratt's. If I understand him correctly, Brongniart writes as follows:—"The mineral consists principally of metallic arsenides and sulphides, and contains usually 6 per cent. nickel and 3 per cent. cobalt, although these proportions are somewhat variable. The mineral is mixed with a small quantity of carbonate of lime and fluor-spar, and heated in a reverberatory furnace to bright red heat; the mass melts at this

high temperature, and we obtain a fluid mass of metallic appearance, also a floating scoria which is removed by aid of a fire-iron. The fluid mass is caused to run out by a special aperture in the furnace, and is sprinkled with water to facilitate crushing, and so broken to pieces. Experience has proved that if the scoria is of a dull colour, it contains iron; if, on the contrary, the surface is black and brilliant, it does not contain iron. The metallic mass is broken to a very fine powder, which is afterwards calcined to a bright red in a furnace; it is heated gradually to avoid fusion, and stirred or worked continually. A large quantity of arsenic is volatilised. The air has free access to the mass, and the weight of oxide is diminished; the calcination, which lasts about twelve hours, is continued until no more white fumes are disengaged. The residue after calcination is treated with hydrochloric acid, which dissolves it almost entirely; the solution is diluted with water, then is added a milk of lime and lime hypochlorite solution or mixture, and it forms a precipitate of iron and arsenic which is rejected after it has been washed . . . . then a current of washed sulphuretted hydrogen gas is passed into the solution . . . . the gas being passed to saturation. The current of gas is arrested when ammonia solution added to a small quantity of the filtered liquid yields a black precipitate; if excess of H_2S gas has not been passed, the precipitate produced by the ammonia will be green. The H_2S gas determines in the solution the formation of a precipitate that is washed, and as it is a little soluble, pass a new current of H_2S through the wash-water; the precipitate is rejected. Afterwards the cobalt is precipitated by means of a solution of hypochlorite of lime; the precipitate washed, dried, then calcined to a red heat; this is considered sesquioxide of cobalt, and is passed into commerce in that form. Another part is heated to a white-red heat. Oxide so treated loses weight and increases in density, and is sold as protoxide of cobalt. . . . . Oxide of cobalt obtained by this method is of remarkable purity, and contains no nickel." (*Traité des Arts Céramiques*, tom. ii. pp. 723, 724.)

Sir Henry Roscoe's description of the process is as follows:—"The roasted ore is fused with a flux of carbonate of lime or sand, when the iron slag flows on to the surface, whilst the cobalt remains below as a heavy *speiss* or stone. . . . . The speiss is then dissolved in strong hydrochloric acid, any arsenate of iron which may be present being precipitated by the careful addition of bleaching-powder solution and a small quantity of milk of lime. The clear supernatant liquid is drawn off, treated with sulphuretted hydrogen for the purpose of separating copper, bismuth, etc., and then the oxide of cobalt is precipitated from the clarified solution by bleaching-powder. The oxide thus obtained is washed and ignited, and this is largely used for colouring glass and porcelain. This oxide usually contains iron, and almost always nickel and other impurities." (Roscoe and Schorlemmer's *Treatise on Chemistry*, vol. ii. part ii. p. 127.)

Hermann describes a method of obtaining the oxide from metallic cobalt by dissolving the metal in nitric acid (the solution being of a rose-red colour); then concentrating and evaporating the solution until it yields the nitrate of cobalt, in small prismatic crystals, which liquefy on exposure to air, and are soluble in alcohol. When the crystals are heated in a retort, and the nitric acid fumes are driven off, black oxide of cobalt remains. (*Painting on Glass and Porcelain*, p. 52, Scott, Greenwood, & Co.)

Properties.—Sp. gr., 6·0 (Roscoe), 5·1 (Jackson). Chemical symbol, Co_3O_4 (Roscoe), Co_2O_3 (Jackson). Chemical composition of the ordinary article of commerce, judging entirely by chemical analysis, is 97·5 per cent. of oxides of cobalt, and 2·5 per cent. lime, iron oxide, copper oxide, zinc oxide, and nickel oxide taken together.

Langenbeck states that the Saxon brands RKO and FKO contain from 5 to 6 per cent. of nickel oxide, the GKO from 2 to 3 per cent., whilst FFKO brand only has ½ per cent.

Black oxide of cobalt commercially comes into the market in the form of a black gritty powder, neutral to test-paper, and yielding a blue bead with borax. Its solution in hydrochloric acid is green or blue, becoming pink when diluted; if the green colour persists on dilution, this indicates the presence of nickel. When calcined, with excess of alumina it gives a blue colour; with oxide of zinc, a green colour; and with magnesia, pale pink. When used as a blue body-stain, it must be wet-ground to an impalpable degree of fineness; otherwise, being an extraordinarily powerful ceramic colourant, dark blue specks will appear on the tiles or wares produced. This oxide is the base of nearly all the other preparations of cobalt now used in the trade.

Prepared Oxide of Cobalt.—This should be simply the black oxide of cobalt reheated to whiteness. In some instances, however, when sold in a finely ground condition, the prepared oxide may be slightly fluxed or adulterated; this, therefore, should be carefully inquired into. Hermann observes that "Cobalt" (referring to the metal) "does not undergo any important alteration at ordinary temperatures, either in air or in contact with water, but on prolonged exposure to red heat, or when roasted with access of air, it oxidises without fusion. The resulting oxide is dark blue (somewhat reddish when accompanied by arsenic), passing into a dark-blue glass—cobalt protoxide—at a strong smelting heat. This consists of cobalt, 83·5; oxygen, 16·5. On prolonged heating to faint redness it takes up more oxygen, assumes a perfectly black colour, and becomes cobalt oxide (black oxide), consisting of cobalt, 80; oxygen, 20. Heated to moderate redness, it reverts to the condition of protoxide, and regains its blue colour." (*Painting on Glass and Porcelain*, p. 52.)

Cobalt Blue.—This term apparently signifies one thing to the practical ceramist, and quite another to the artist in oil or water colours. For the

latter Hurst describes it as essentially a compound of the oxides of cobalt and alumina; some makers also adding phosphoric acid. It is prepared either by mixing solutions of alum and cobalt in the proportion of 1 lb. of cobalt nitrate to 12 lbs. alum, and precipitating with carbonate of soda, and calcining the precipitate at a red heat; or by mixing eight parts of alumina with one part of cobalt phosphate, and heating in a crucible for from half to three-quarters of an hour at a bright red heat, then grinding the calcined mass in water. But neither of the foregoing answers to the description and characteristics of the article commercially known as cobalt blue in the ceramic industry; this latter is of a rich violet or bluish-pink colour, very like the compound resulting from a mixture of cobalt oxide and Cornish stone calcined and ground. Upon analysis by Joseph Lones, Esq., F.I.C., F.C.S., Smethwick, a sample of cobalt blue, as used by ceramists, yielded:—

Silica,	39·63
Cobalt oxide,	56·63
Lime,	1·90
Phosphoric acid,	0·12
Organic matter,	0·35
Moisture,	1·01

Carbonate of Cobalt may be prepared by heating chloride of cobalt to 140° with a solution of sodium bicarbonate saturated with carbon dioxide. This is the normal salt $CoCO_3$, a red powder. The hydrated carbonate $CoCO_3+6H_2O$ may be obtained by "allowing mixed solutions of cobalt nitrate and sodium bicarbonate, saturated with carbon dioxide, to stand exposed to a low temperature until the amorphous precipitate which is first formed becomes crystalline; the dry salt is converted into the anhydrous salt on warming." (Roscoe's and Schorlemmer's *Treatise on Chemistry*, vol. ii. part ii. p. 133, Macmillan.)

Roscoe further remarks that "When a cold or hot solution of a cobalt salt is precipitated with normal or acid sodium carbonate, bluish or violet basic cobalt carbonates of varying composition are thrown down." (*Ibid.*, p. 133.)

Hence in purchasing and using this preparation some care should be exercised in specifying the particular carbonate of cobalt dealt with.

Cobalt Chloride, $CoCl_2$.—For staining purposes the use of solutions of cobalt is sometimes advocated as a means of avoiding speckiness in the ware. For this purpose a solution of the chloride is used, and by previously assuring the presence of sufficient sodium carbonate in the body or glaze slip, the cobalt is assumed to be, when intimately mixed therewith, precipitated as carbonate, and so fixed in a more perfectly diffused state than can be effected by calcining and grinding and mixing body-stains in the usual manner. How far this has been put into actual practice is unknown to the writer. There are, however, some possibilities that need providing for in such a case, namely,

loss by filtration through the clay-filter presses, action of the acids on pumps and press cloths, incorrect adjustment of the solutions.

Cobaltous Silicate is another preparation of cobalt of which Hermann speaks in highest terms, and Hermann seems to have gathered his information largely from the writings of Paul Randau. He remarks that "As the blue colour yielded by cobalt oxide is finer in proportion as the oxide is purer, especially as regards freedom from iron, the merely roasted cobalt ore cannot be employed for producing a fine blue colour in glass, porcelain, and enamel. The presence of nickel in quantity also produces a dirty blue colour. . . . . It is therefore important, both for this object and for enamel painting, to have cobalt preparations free from foreign materials, especially such as may act prejudically on the colour. The very best preparation for this purpose is cobaltous silicate, and no manufacturer producing coloured enamels should neglect to make this preparation for himself, since in beauty of colour it far surpasses the products generally employed. . . . . For the production of this substance, the cobalt ores, cobalt glance, smaltine, etc., can be used. The ore is reduced to a coarse-grained powder, and roasted with unrestricted access of air, whereby the greater part of the arsenic present in many cobalt ores is volatilised in the form of arsenious acid (white arsenic). [Query, what becomes of the arsenic?] The residue is stirred up to a thick gruel with concentrated sulphuric acid, and is then heated to strong redness in a furnace and treated with water.

". . . . When the roasted mass is brought into contact with water, only a small amount of ferrous sulphate passes into solution along with the cobaltous sulphate. To remove the former, small quantities of soda solution are added to the liquid. This causes, in the first place, the deposition of iron oxide from the solution as a brown precipitate, and with a little practice the moment when the last trace of iron oxide has come down can be sharply defined. Immediately cobaltous carbonate begins to precipitate, it is recognisable by its pale-blue colour. The cobalt solution, now free from iron, is next filtered from the ferric hydrate precipitate, and cobaltous silicate is thrown down, as a pale-blue sediment, by means of a solution of water-glass (sodium silicate). This precipitate is washed, dried, and fused, and then forms a very dark but pure blue mass, which is particularly suitable as a pigment for enamel." (*Painting on Glass and Porcelain*, p. 56.)

Nickel Oxide.—The compound of nickel usually employed by ceramists is the monoxide, which is chiefly obtained either by precipitation from residual solutions remaining after cobalt has been precipitated in the preparation of cobalt oxide, or by some more direct treatment of one of the ores of nickel.

Ores of nickel occur in Scotland (at Newton-Stewart), in Cornwall, Saxony, Hartz, Bohemia, New Caledonia, France, and Canada. In the Museum of Practical Geology, Jermyn Street, London, are specimens of two

beautiful green minerals (garnierite and noumeite), being hydrated silicates of nickel and magnesia from New Caledonia.

Preparation.—In the process of manufacturing cobalt, after the cobalt has been precipitated by bleaching-powder, the nickel contained in the clear solution is precipitated as the hydroxide or carbonate, by milk of lime or soda-ash. This is then ignited and purified by treatment with hydrochloric acid, when the excess lime and carbonate of lime dissolve. If $CaSO_4$ be present, the impure oxide is heated with steam, and soda-ash solution added in such quantity that after boiling for quarter of an hour an excess still remains. The Na_2SO_4 is then removed by washing with water, and the $CaCO_3$ dissolved in dilute hydrochloric acid. (Roscoe and Schorlemmer.)

Properties.—Sp. gr., 5·2. Chemical symbol, NiO. It is an ashy-grey powder, soluble in acids.

I am indebted to the Metallic Oxides Co., Irvine, N.B., for the following chemical analysis of their product :—

ANALYSIS OF COMMERCIAL OXIDE OF NICKEL.

Nickel oxide,	87·61
Lime,	1·53
Magnesia,	3·10
Alumina,	0·50
Ferric oxide,	0·43
Silica,	2·50
Sulphuric anhydride,	1·30
Combined water,	1·60
Moisture,	1·20
	99·77

In numerous experiments with this ingredient in glazes, it has never appeared to yield satisfactory or constant results; and for my own part I should avoid its introduction in glazes whenever similar effects could be attained by other means. In bodies of a vitreous kind for mosaics it forms a useful material for producing a bronze-green tint.

Langenbeck remarks that "Nickel oxide itself is not used very extensively, from the fact that in the more convenient glazes, which are rich in lead oxide and boracic acid, it is very liable to cause turbid loam-coloured separations, and to shade badly from brownish to greenish tints. It is, however, serviceable in the more alkaline glazes and those poor in boracic acid." (*Chemistry of Pottery*, p. 133.)

Whatever value nickel oxide has in glazes, its effects appear to be favoured by the presence of lime.

Respecting its physiological tendencies, the Metallic Oxide Co. remark :—"We do not find it in any way injurious to the health of those who work at it."

Copper Compounds.—The preparations most generally used are the black oxide, red oxide, and carbonate; and the sources are practically the

metallic copper and blue vitriol of commerce, the latter being manufactured on an enormous scale for horticultural purposes.

Black Oxide of Copper is often prepared by ceramists by simply calcining old copper-plates with free access to air, then breaking and separating any unoxidized portions. It may also be made by heating nitrate of copper to redness, or by igniting the carbonate.

Red Oxide of Copper may be obtained in several different ways:—(1) By heating in a covered crucible a mixture of five parts of black oxide of copper and four parts of fine copper filings (Fownes). (2) By adding grape sugar to a solution of copper sulphate, then adding potash caustic in excess; the resulting blue solution is then boiled, when Cu_2O is deposited (Fownes). (3) By gently heating a mixture of five parts of cuprous chloride and three parts of carbonate of soda in a covered crucible and lixiviating the residue (Roscoe). But Hermann, in his work on *Painting on Glass and Porcelain*, tells us that "The easiest method of preparation is that of Malaguti. One hundred parts of cupric sulphate are heated with seventy-five parts of crystallised sodium carbonate at a moderate heat until the whole has solidified. The mass is then pulverised and mixed accurately with twenty-five parts of copper filings, and exposed to a white heat in a crucible for twenty minutes; on cooling it is powdered and washed, the residue consisting of red cuprous oxide."

Carbonate of Copper.—This occurs native as *Malachite* in certain mines in Derbyshire, Persia, and Egypt. Its commercial preparation is effected, however, by precipitating a cold solution of copper sulphate by sodium carbonate. This yields a blue precipitate of copper carbonate and hydrate. This on standing is converted into a green powder (Roscoe). Fownes observes that the precipitate is at first pale blue and flocculent, but by warming it becomes sandy and assumes a green tint.

Physiologically, copper compounds are undesirable ingredients, because the poisonous nature of soluble copper salts necessitates precaution in their use in glazes. And so far as commercial black oxide of copper is concerned, a firm of merchants handling this article largely, in reply to an inquiry, wrote, "Everything in copper oxide is poisonous."

Chromium Compounds.—The compounds of chromium most usually employed by ceramists are chrome iron-ore, bichromate of potash, green oxide of chromium, and the chromates of lead, barium, calcium, and tin.

Chrome Iron-Ore is a native ferrous chromate. It is found in the Shetland Isles, Styria, the Urals, France, Asia Minor, New Zealand, New Caledonia, Newfoundland, Canada, Pennsylvania, Maryland, North Carolina, and California. As to the actual commercial sources at the present time, we learn from the report on the *Mineral Resources of the United States for 1901* that "By far the greater part of the chromite used in the United States is obtained from the deposits of Asiatic Turkey. . . . . These are probably the

most extensive chromite mines now in operation, and they furnish the larger part of the chromite supply of the world. The ores usually carry from 50 to 52 per cent. of chromite oxide. The New Caledonia deposits are beginning to be worked to some considerable extent. The ore is, as a rule, shipped from Numea to Australian ports, and thence to Europe as ballast in ships laden with wool. . . . . The Canadian chromite deposits in the Black Lake region of the province of Quebec are still producing." (*Min. Res. U.S.*, *1901*, p. 946.)

Its specific gravity is about 4·3, and its chemical composition varies between the following extremes:—40–60 per cent. Cr_2O_3, 18–38 per cent. FeO, 2–19 per cent. Al_2O_3, 0–18 MgO.

Its principal use in ceramics is in making underglaze colours, mostly the various shades of brown.

Musspratt gives its analysis thus:—

Magnesia,	7·49
Iron,	20·99
Oxide of chromium,	59·96
Alumina,	11·56
	100·00

Bichromate of Potash.—In the preparation of this, the chrome iron-ore is first roasted and finely ground; then four and a half parts of finely ground ore are mixed with two and a quarter parts of potassium carbonate and seven parts of lime. This mixed mass, after drying at 150°, is heated to bright redness with an oxidizing flame, the whole being constantly stirred. Subsequently the charge is withdrawn from the furnace, and after cooling it is lixiviated with the minimum amount of hot water. The calcium is then precipitated as sulphate, and the liquor is next treated with the requisite quantity of sulphuric acid diluted with twice its volume of water, to convert the chromate into dichromate, and then allowed to cool. About three-quarters of the dichromate precipitates on cooling. This is collected and recrystallized. (Roscoe and Schorlemmer.)

Properties.—Sp. gr., 2·692. Chemical symbol, $K_2Cr_2O_7$. Melts below a red heat into a transparent liquid, which crystallizes again when slowly cooled. It decomposes at a white heat into oxygen, chromic oxide, and normal or yellow chromate of potassium (Roscoe). The commercial salt is almost chemically pure.

Physiologically, "It acts as a powerful poison" (Roscoe). Great care should therefore be exercised when handling solutions of bichromate of potash; most particularly if any cut or abrasion of the skin of the hands exists. Those having to do with washing U.G. pink colour frequently have their hands injured by the solutions, and painful skin diseases are sometimes induced by carelessness in this respect.

Green Oxide of Chromium.—The customary method of preparation of this

ingredient by ceramists is to burn a mixture of sulphur (one part) and bichromate of potash (five parts) in a biscuit earthenware vessel, on the top of a potter's glost oven; then grind for use, washing very thoroughly.

The possibility of sulphur fumes being mischievous in the kiln would suggest some other place perhaps as more suitable for conducting the calcination; but, after all, no doubt far greater volumes of sulphurous gases already enter the kilns from the fuel consumed.

The advantages of any method of home production of this ingredient are that purity is thereby assured. No adulterations such as are used in the green colours made for house decorators' use being introduced, the ceramist's mind is set at rest on that score, and less loss is occasioned.

Particularly fine quality of green oxide of chromium may be prepared by gently igniting in a covered crucible mercurous chromate.

Hermann observes that, according to Jean, the waste chrome alum from aniline green and aniline violet works is now used for preparing chromic oxide. To this end one part of chrome alum is strongly calcined with three parts of carbon. Sulphurous acid is evolved, and a mixture of potassium sulphate and chromic oxide remains behind, and can be separated by means of water.

Properties.—Sp. gr., 5·01. Chemical symbol, Cr_2O_3. Chemical composition, 68·6 chromium, 31·3 oxygen. Loss on calcination with a flux probably *nil.* Almost insoluble in acids.

To secure really fine tints of green oxide of chromium, it is necessary to purify the bichromate of potash by recrystallization so as to remove salts of iron that are very detractive to the tint (Hermann).

Uranium Compounds.—Professor Rutley gives the following list of countries as sources of uranium ores: Cornwall (at Grampound Road), Saxony, Bohemia, Norway, and Turkey. The *Report on the Mineral Resources of the United States, 1901*, refers to occurrences of ores of uranium in several of the states.

The minerals or ores are mostly pitchblende, uraconite, uranite; but they are only found sparingly, as a rule, and, by consequence, uranium is considered a comparatively rare element.

Green Oxide of Uranium, "$U_3O_8 = UO_2 + 2UO_2$, occurs more or less pure in pitchblende. The pure oxide can be obtained by gently heating the trioxide or the dioxide in the air, in the form of a satiny dark green powder, having a specific gravity of 7·2, and soluble in strong acids." (Roscoe and Schorlemmer's *Treatise on Chemistry*, p. 222.)

Black Oxide of Uranium, "$U_2O_5 = UO_2 + UO_3$, is formed when the other oxides, or ammonium uranate, are strongly ignited in the air. It is a black powder used for painting on porcelain." (Roscoe and Schorlemmer.)

Uranium Yellow, sodium uranate, $Na_2U_2O_7$.

Preparation.—It may be obtained by precipitating a uranic salt by excess of

soda, or by fusing uranic oxide with soda carbonate. "It is prepared on the large scale by roasting one hundred parts of pitchblende, containing 45 per cent. of U_3O_8, with fourteen parts of lime in a reverberatory furnace. The resulting calcium uranate is treated with dilute sulphuric acid, and the solution of uranic sulphate thus obtained is mixed with sodium carbonate. The uranium is precipitated together with the other metals, but redissolves in an excess of the alkali. On treating this liquid with dilute sulphuric acid, a hydrated sodium uranate, or uranium yellow, $Na_2U_2O_7+6H_2O$, is obtained." (Roscoe and Schorlemmer.)

Titanium Compounds.—From Professor Rutley we learn that the minerals containing titanic dioxide are *Rutile*, *Anatase*, and *Brookite*; and that titanic dioxide also exists, in conjunction with lime and silica, in the mineral *Sphene*, and in association with iron in the mineral menaccanite, which occasionally contains as much as 50 per cent. The presence of titanic dioxide is now being more often determined in chemical analyses of clays, and is found to exist in appreciable quantities, often between one and three per cent.; and we now learn from Mr. W. O. Snelling that when TiO_2 is not separated it is reported with the alumina.

Rutile occurs compact and massive, and is usually of a reddish-brown, red, yellowish, or black colour. Its hardness is 6 to 6·5, and its sp. gr. 4·18 to 4·25. It is composed of titanic acid usually with a little peroxide of iron; the TiO_2 being present in the proportion of from 96·5 to 98 per cent. Alone it is infusible at temperatures attained in ordinary laboratory apparatus. It is found in Perthshire, Argyleshire, and Ireland; also at St. Yrieix near Limoges, France, and in Norway, Spain, and U.S.A.

Anatase differs but little from rutile, but is of inferior hardness and sp. gr. It is found at Tavistock, Liskeard, Tintagel, and Tremadoc, in Great Britain; and is abundant in Dauphiné, France. It also occurs in Bavaria, Norway, and Brazil. The same districts frequently yield brookite.

Sphene, in colour, may be brown, grey, yellow, green, or black, but it yields a white streak. Sp. gr., 3·4 to 3·56. It contains usually 30 to 35 per cent. silica, 33 to 43 per cent. titanic acid, and from 21 to 33 per cent. of lime, a little oxide of manganese being present in the variety called greenorite. (Rutley's *Elements of Mineralogy*, p. 32, Murby.)

The article in the *Report of U.S. Geol. Survey on the Mineral Resources of U.S., 1901*, by W. O. Snelling, however, brings us a little more up to date as to the present commercial sources. Mr. Snelling writes:—"The recent discovery of large deposits of rutile in Virginia has brought to the attention of the ceramic and steel industries the commercial possibilities of this ore of titanium. . . . Minerals containing titanium are found widely distributed, and in such large quantities as to make titanium a relatively abundant element. The idea so generally held of the comparative rarity of titanium

in nature is quite erroneous, as has been shown by Dr. F. W. Clarke's researches. . . . . Dr. Clarke has shown that titanium is relatively more abundant in the known portion of the solid crust of the earth than manganese, carbon, or sulphur. Nearly all the text-books on chemistry speak of titanium as one of the very rare metals, and class it with cerium or even thorium, although it is found in nature in greater quantity than all of the thirty rarer elements taken together.

"In some places, particularly in the Adirondacks, and to a lesser extent in many other parts of the earth, titaniferous iron-ores are found in enormous quantities. . . . .

"The most abundant of all the titanium minerals is ilmenite (ferrous titanate, $FeTiO_3$), which, combined with varying quantities of ferric oxide, is found concentrated in beds of great extent, particularly at Kragerö in Norway, Bay St. Paul in Canada, and in Rhode Island, Connecticut, New York, North Carolina, Pennsylvania, and Vermont in the United States.

"*Ilmenite* is generally found massive, and less often in irregular grains, both forms showing submetallic luster, iron-black colour, specific gravity of 4·7 to 5·1, and hardness varying from 5·5 to 6. When a crystalline structure is apparent, its form is rhombohedron of the hexagonal system.

"*Rutile* (titanium oxide, TiO_2) is generally found wherever large deposits of ilmenite occur; and besides the localities mentioned for ilmenite, it is found in notable quantities at Groves Mountain, Georgia; Magnet Cove, Arkansas; and in Nelson County, Va. Rutile usually occurs in tetragonal prismatic crystals, yellow-brown or red in colour, specific gravity 4·2, adamantine luster, and hardness varying from 6 to 6·5. Both ferric oxide and titanium oxide unite with ferrous titanite (ilmenite) in all proportions, forming a series of compounds varying continuously in composition between the limits TiO_2 and Fe_2O_3. Thus we have light-yellow rutile, consisting of practically pure titanium oxide; darker coloured rutile, containing a small quantity of $FeTiO_3$; then black rutile (nigrine), containing a relatively greater proportion of $FeTiO_3$; and so on. . . . . (*Mineral Resources U.S.*, *1901*, p. 272.)

Properties.—When pure titanium dioxide is introduced either into a body or glaze, in the absence of other colourant oxides, the writer's experience has been that no colour results, but merely an incipient opacity partaking of the nature of that induced by tin oxide or antimony oxide. It would be interesting to know the experience of others in this respect. It also appears that, when introduced into borax glazes, titanic oxide produces turbidity such as nickel oxide and tin oxide produce.

When, however, the native titanic oxide, rutile, which, as we have seen, is partly composed of ferrous titanate, is introduced in vitreous bodies of felspathic character, a yellow or buff tint is imparted, varying in tint and

intensity according to the particular quality of rutile employed, the proportions used, and the nature of the associated body or composition.

There is probably a wide field of research open for ceramists in these refractory compounds of titanium.

The French appear to have been particularly fortunate in their early attention to this material, which, luckily being found at St. Yrieix, early came under their notice.

Brongniart, more than fifty years ago, employed rutile or natural oxide of titanium for producing yellow-tinted hard porcelains and stoneware bodies. (See *Traité des Arts Céramiques*, tom. ii. p. 624.)

Mr. W. O. Snelling, in the U.S. report already referred to, among other things observes that: "Under favorable conditions titanium oxide imparts to porcelain a fine yellow color. It is capable of being used with other substances to produce secondary colors, and it will withstand without difficulty the heat of the kiln, although at very high temperatures it increases the fusibility of the porcelain somewhat, acting as a flux. The ware containing titanium oxide must, however, be entirely shielded from the action of the gases resulting from combustion, and it has been neglect of this important precaution that has resulted in the failures to obtain satisfactory results from this pigment. In the manufacture of artificial teeth, where titanium oxide forms the pigment universally used (and with perfect success), the walls of the muffle are coated with clay before each firing, thus effectually preventing reducing gases from injuring the ware. When TiO_2 is reduced by carbon monoxide, the lower oxide Ti_2O_3 may be produced. This is a copper-red compound, and corresponds in color to the effect produced when paste containing titanium is fired in presence of reducing gases. . . . .

"It might be questioned if, in view of the difficulties presented, the use of titanium oxide could be made commercially successful, and this question is deserving of careful consideration. In the first place, the fusible properties of the paste might be corrected by diminishing slightly the usual quantity of feldspar, and thus this fault could be quickly eliminated. But to prevent the access of furnace gases is much harder. The only way to accomplish this which seems at all practicable is to have the saggers gas-tight, even though luting might be necessary to effect this. . . . . It must be admitted that in general use the TiO_2 is not likely to be very successful, although for particular cases, when the results sought justify a great amount of work in the preparation of the finished goods, a good field is opened for trials of this pigment. The composition of the body used for artificial teeth is kaolin, feldspar, and silica, in approximately the proportion by weight: kaolin, 6 per cent.; silica, 19 per cent.; and feldspar, 75 per cent. And although this composition varies widely from the proportions of these substances as used in pottery, the difference is not essential, and would produce no alteration in the effect with

TiO_2, which is mixed with the paste in quantity varying with the color wanted, from one-half of one per cent. to several per cent. The production of artificial teeth in the United States has been estimated to reach eight millions annually, and in all of these titanium oxide is the pigment employed. This shows the degree of success which has attended its use in the dental industry." (*Min. Res. U.S.*, *1901*, p. 275.)

While admitting the accuracy of many of Mr. Snelling's observations and inferences, there are several points that need qualification, and perhaps further investigation. Without attempting any seriatim review of his notes upon the subject, which we have shown appreciation of by reprinting here, the writer submits, for further experiment by those concerned, that there is a possibility that, after all, pure TiO_2 produces colourless or opaque white effects in ceramic compositions, and that the various shades of yellow and buff obtained arise from the presence of ferrous titanate.

TABLE OF SPECIFIC GRAVITIES, COMBINING WEIGHTS, THEORETICAL COMPOSITION, ETC., OF POTTERS' MATERIALS.

Substance.	Specific Gravity.	Chemical Symbol.	Combining Weight.	Theoretical Percentage Composition, omitting Traces.
Alumina, hydrated, . .	4·2	$Al_2O_3,3H_2O$	156	65·4 Al_2O_3, 34·6 H_2O
,, calcined, . .	3·75–4·0	Al_2O_3	102	100 Al_2O_3
Barium, carbonate, . .	4·3	$BaCo_3$	197	77·7 BaO, 22·3 CO_2
Barytes, ...	4·6	$BaSO_4$	233	65·7 BaO, 34·3 SO_3
Borax, crystals, . .	1·71	$Na_2B_4O_7+10H_2O$	382	16·23 Na_2O, 36·65 B_2O_3, 47·1 H_2O
,, fused, . . .	...	$Na_2B_4O_7$	202	30·7 Na_2O, 69·3 B_2O_3
Boric acid, crystals, . .	1·43	$B_2O_3,3H_2O$	124	56·4 B_2O_3, 43·5 H_2O
,, anhydrous, .	1·83	B_2O_3	70	100 B_2O_3
Calcium oxide, . .	3·08	CaO	56	100 CaO
,, carbonate, . .	2·0–2·9	$CaCO_3$	100	56 CaO, 44 CO_2
China-clay (kaolin), .	2·26	$Al_2O_3,2SiO_2,2H_2O$	258	46·5 SiO_2, 39·6 Al_2O_3, 13·9 H_2O
,, calcined, .	2·35	Al_2O_3, $2SiO_2$	222	54·1 SiO_2, 45·9 Al_2O_3
Cornish china-stone,[1] .	2·6	$18SiO_2,2Al_2O_3,K_2O$	1378	78·4 SiO_2, 14·8 Al_2O_3, 6·8 K_2O
Cobalt oxide, black, .	5·1	Co_2O_3	165	100 Co_2O_3 (Jackson)
,, ,, .	6·0	Co_3O_4	240	(Roscoe)
Copper oxide, black, .	6·3	CuO	79·5	100 CuO
Chrome oxide, green, .	5–5·2	Cr_2O_3	153	100 Cr_2O_3
Ferric oxide, . . .	5·9	Fe_2O_3	160	100 Fe_2O_3
Felspar, orthoclase, . .	2·5–2·7	$K_2O,Al_2O_3,6SiO_2$	556	64·7 SiO_2, 18·3 Al_2O_3, 16·9 K_2O
Flint, calcined, . .	2·4–2·6	SiO_2	60	100 SiO_2
Gypsum, ...	2·33	$CaSO_4,2H_2O$	172	32·5 CaO, 46·5 SO_3, 21 H_2O
Magnesia, calcined, . .	3·0–3·6	MgO	40	100 MgO
Manganese dioxide, black,	4·82	MnO_2	87	100 MnO_2
,, carbonate, .	3·5	$MnCO_3$	115	61·7 MnO, 38·3 CO_2
Nickel oxide, . . .	5·2	NiO	75	100 NiO
Plaster of Paris, . .	2·37	$CaSO_4,\frac{1}{2}H_2O$	145	38·6 CaO, 55·2 SO_3, 6·2 H_2O
Potassium oxide, . .	...	K_2O	94	100 K_2O
Potass. carbonate, . .	2·3	K_2CO_3	138	68·1 K_2O, 31·9 CO_2
Quartz, ...	2·6	SiO_2	60	100 SiO_2
Soda-ash, calcined, . .	2·44	Na_2CO_3	106	58·5 Na_2O, 41·5 CO_2
Soda crystals, . . .	1·45	$Na_2CO_3,10H_2O$	286	21·7 Na_2O, 15·4 CO_2, 62·9 H_2O
Sodium oxide, . . .	2·8	Na_2O	62	100 Na_2O
Tin oxide, white, . .	6·7	SnO_2	150	100 SnO_2
Zinc oxide, white, . .	5·6	ZnO	81	100 ZnO

[1] Cornwall stone is given as 1 RO, 2·5 Al_2O_3, 20 SiO_2, in *Man. Cer. Calculation* (*Trans. Am. C.S.*)

CHAPTER V.

CERAMIC PYROMETRY.

CONTENTS.—Wedgwood's pyrometer—Kirkup's contraction tables—Brongniart's pyrometer—Seger cones—Professor Orton's batch-weights for cone compositions—Holdcroft & Co.'s thermoscope—Watkin's heat recorders—A.B.C. pyro-indicators—Professor Sir Roberts-Austen's electrical pyrometer—Le Chatelier's pyrometer—The "Queen" electrical pyrometer—Cambridge electrical pyrometer—Automatic wireless electrical pyrometry—Immersion thermometer.

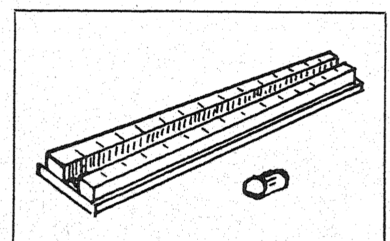


FIG. 170.—Pyrometer.

THE most complacent ceramist will hardly venture to claim that, in actual manufacturing practice, pyrometry of ovens and kilns has been reduced to a science. Efforts have been made to acquire a mastery of the subject, and recent inventions have undoubtedly rendered possible greater control over the burning, and more accurate observation of the temperatures attained.

Still, no single instrument has, in general practice, altogether superseded the time-honoured fireman's trials, nor relieved him of his heavy responsibility. Wherever capability and experience are wanting, losses, whose name is legion, still insidiously sap the prosperity of the industry.

Referring to the measurement of temperature in general, Mr. Robert S. Whipple observes that "Although we are, perhaps, apt to laugh at the very rough methods adopted by our predecessors for the measurement of temperature, it cannot be denied that accurate temperature measurement is still a problem of considerable difficulty. Temperature is not a measurable quantity in the strict sense of the term. To measure a length or a mass is to count how many times it is necessary to take a given body chosen as a unit (metre or gramme, as the case may be) in order to obtain a system equivalent either as regards length or mass to the body in question.

"The possibility of such a measurement presupposes the existence of two laws—that of equality and that of addition. Temperature obeys the first of

these laws. Two bodies in temperature equilibrium with a third will also be in equilibrium with each other. The other law is entirely lacking. It is impossible by the juxtaposition of several bodies at the same temperature to realise a system equivalent from the point of view of exchange of heat to a body of different temperature.

"In order to measure temperature one observes any phenomenon whatever, varying with change of temperature. These phenomena are of various kinds, but the expansion of bodies has been selected as the easiest to observe. Thus for the mercury Centigrade thermometer the temperature is defined by the apparent expansion of mercury from the point of fusion of ice to the ebullition of water under atmospheric pressure ; this apparent expansion is divided into one hundred parts, each part being called one degree.

"Many scales of temperature have been proposed, but the gas scale is the one now universally adopted, and readings obtained by any type of thermometer, electrical, expansion, or optical, are reduced to temperatures on this scale. . . . . It is impossible to enter here into the details of the construction and working of a gas thermometer, and I would refer those who are specially interested to Dr. Guillaume's book, *Thermométrie de Précision*, or Dr. Burgess's translation of M. Le Chatelier's book, *High Temperature Measurements*. . . . . The gas thermometer, although invaluable from the strictly scientific point of view, is practically useless as a tool in every-day life."

Mr. Whipple then proceeds to explain at some length the various means of measuring temperature in general use. Some of these we shall have occasion to refer to at a subsequent stage in this chapter.

Wedgwood's Pyrometer.—Of this pyrometer Dr. Ure wrote:—"The most celebrated instrument for measuring high temperatures is that invented by the late Mr. Wedgwood, founded on the principle that clay progressively contracts in its dimensions as it is progressively exposed to higher degrees of heat. He formed his white porcelain clay into small cylindrical pieces in a mould, which, when they were baked in a dull red heat, just fitted into the opening of two brass bars fixed to a brass plate so as to form a tapering space between them. This space is graduated, and the farther the pyrometric clay-gauge can enter, the greater heat does it indicate. The two converging rules are placed at a distance of 0·5 of an inch at the commencement of the scale and of 0·3 at the end." (Ure's *Dictionary of Chemistry*, p. 696.)

Judging by Dr. Ure's excerpts from Wedgwood's own description of his instrument, it would seem that, however useful it proved to be in actual practice, Wedgwood was in error as to the degrees Fahrenheit at which metals such as iron, gold, and silver melted, and thus upon attempting comparisons of his own pyrometer with degrees Fahrenheit he assumed figures that later investigators found to be erroneous.

Omitting further notice of these, of which the details would be misleading,

we may with advantage quote and examine Wedgwood's own comparisons of the degrees on his pyrometric gauge with natural phenomena, including the melting-point of metals.

Red heat fully visible in the dark	$-1°$	Wedgwood's gauge.
Do. do. in daylight	$0°$	do.
Swedish copper melts	$27°$	do.
Fine silver melts	$28°$	do.
Fine gold melts	$32°$	do.
Cast-iron melts	$130°$	do.

Here it is seen that Josiah Wedgwood places the melting-point of gold at 32° on his pyrometer, and that of silver at 28°, a difference of 4° W.

Now, according to authorities of our times, the melting-point of gold is about 1075° C., and of silver about 960° C., a difference of 115° C. $115 \div 4 = 28\frac{3}{4}$, therefore an advance of $1°$ W. $= 28\frac{3}{4}°$ C.

But Josiah Wedgwood also places the melting-point of cast-iron at 130° W., and of silver at 28° W., *i.e.*, a difference of 102° W.

Now, the melting-point of cast-iron is to-day placed at about 1230° C., and it has already been shown that that of silver is about 960° C., a difference of 270° C. Now $270 \div 102 = 2{\cdot}64$, therefore $1°$ W. $= 2{\cdot}64°$ C.; but it has been shown that $1°$ W. $= 28\frac{3}{4}°$ C., which is contradictory.

To criticise the statements of such a distinguished ceramist in his absence is placing him at a great disadvantage, but this course is unavoidable in any attempt to appraise his views on ceramic pyrometry.

By the courtesy of Mr. Alfred J. Caddie, curator of the Public Museum, Stoke-upon-Trent, we are enabled to illustrate a pyrometer purporting to be the original Wedgwood pyrometer (fig. 171), also some of the test-pieces belonging thereto (fig. 172).

This instrument is believed to have been handed over to the Public Museum by the authorities or trustees of the old Athenæum of Stoke-upon-Trent; and the Athenæum is said to have become possessed of it by the gift of Dr. Garner, who either presented or bequeathed many antiquities and naturalist specimens to that institution. The curator states that the instrument has always been spoken of as originally Josiah Wedgwood's.

It will be observed that there are two grooves on the instrument, each carefully marked off in degrees. It is also marked in one part by a peculiar cypher or code which possibly may some day lead to its more certain identification.

Wedgwood's system was adopted by many manufacturers of pottery, and, until a few years ago, such gauges might frequently be seen in actual use; for so long as care was taken in compounding the body of the test-pieces, and so long as the temperatures generally used did not exceed the point at which the test-body would begin to expand again, the pyrometer was approximately

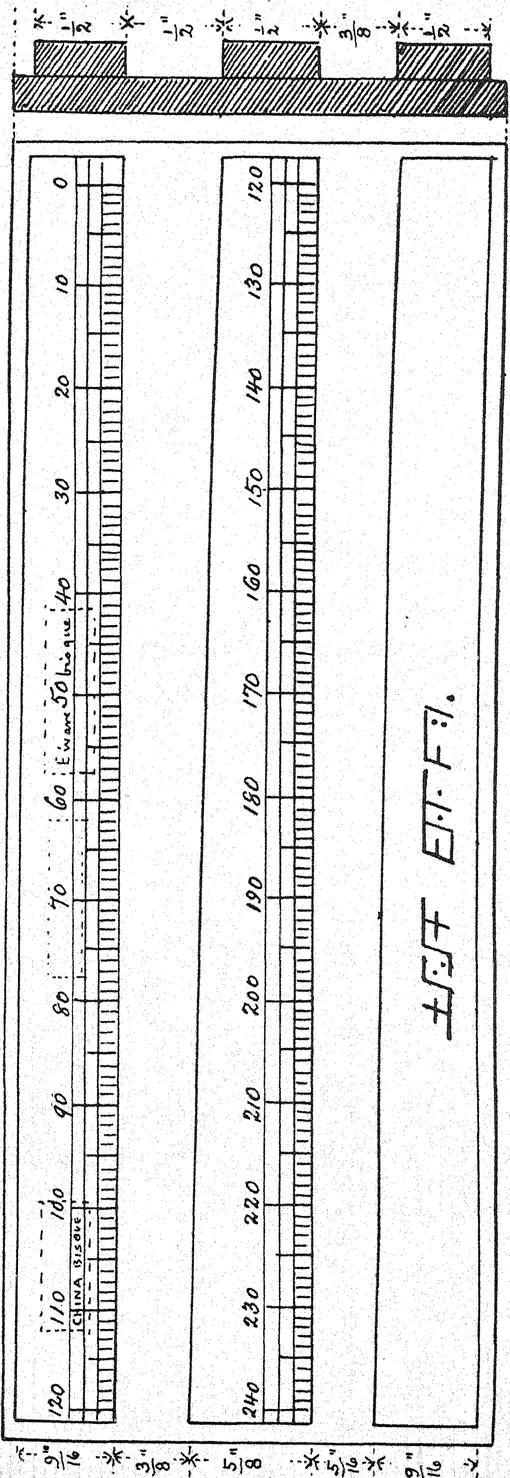


FIG. 171.—Wedgwood's Pyrometer, Stoke-upon-Trent Museum.

indicative of what was occurring inside the kilns; indeed, Mr. Cecil Wedgwood says the system is still used at their Etruria works.

Professor C. F. Binns, writing of Wedgwood's pyrometer, observes:—"To this method there are two great objections. First, the extreme difficulty of obtaining continual supplies of clay absolutely uniform in shrinkage; and second, the fact that contraction does not correctly indicate the amount of firing or the degree of heat. For example, in the china biscuit oven all the contraction will have left the body long before the point of translucence is reached; and further, in most, if not in all wares, after the shrinkage has taken place a reaction will set in under continued fire, resulting in a slight expansion which would entirely upset any calculation based upon delicate measurements." (*Ceramic Technology*, p. 57, Scott, Greenwood, & Co.)

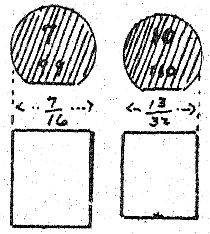


FIG. 172.—Pyrometer test-pieces.

And Hermann (translated by Charles Salter) wrote of Wedgwood's pyrometer thus:—"Fourmy has shown . . . . that this instrument does not fulfil all the necessary requirements, in that the shrinkage of the clay is not constant at a given temperature, but depends on the rate of heating. According to

the nature and preparation of the clay employed, and the degree of compression undergone by the mass in forming the cylinder or cube, the variations in the latter will differ at one and the same temperature side by side in the same furnace. . . . . By reason of this uncertainty and irregularity of recording, the Wedgwood pyrometer is now seldom used." (*Painting on Glass and Porcelain*, p. 247, Scott, Greenwood, & Co.)

Mr. Henry Watkin's criticism of Josiah Wedgwood's method of ascertaining the degree of firing is much more qualified and moderate, and bespeaks considerable practical acquaintance with the requirements of the potter—particularly the Staffordshire potter. Among other things, he has remarked: "It is quite conceivable that a body could be compounded which would commence to contract at a No. 12 recorder (= 920° C.), and continue to contract steadily up to about 1350° C.; such a body would then cover all the ranges which are commonly employed in the English manufacture. At a later stage in this paper reference will be made to a body which has actually fulfilled these requirements." (*Trans. N.S.C.S.*, vol. ii. p. 80.)

Mr. Watkin tritely points out that "Pottery firing is not conducted for the estimation of the temperatures, but for the purpose of increasing the density and vitrescence of the ware"; and he continues, "Contraction, density, and vitrescence, which always accompany the firing of pottery, are not necessarily produced at any given degree of heat. The contraction and increase of density as the result of firing is not always strictly proportionate to the degree of heat to which such bodies have been exposed."

Further, he experimentally demonstrated that variations arose even from unequal bulks of clay exposed to given temperatures. (*Trans. N.S.C.S.*, vol. ii. p. 89.) He cites as an example two glass rods of varying thickness placed over a bunsen-burner; one would bend very much quicker than the other. In like manner he instanced two potteries working from the same body—one making hollow wares, the other heavier and thicker wares—in which a difference of 40° C. in the firing points was necessary; in other words, the ware at one factory was as hard when fired up to Cone 3 as at the other when fired to Cone 5. (*Ibid.*)

At the same time Mr. Watkin emphasized another point, namely, that "There is very great reason to suppose that the heat is much more powerful in some places than in others." Showing an example, he added, "It will be seen by the small recorder shown herewith that on an article not longer than 50 mm. the contraction has been more than double at one end to that which has taken place at the other. If, then, on an article of only 2 inches in length such an immense diversity can occur, it is very desirable indeed that the firing should be conducted in such a way that the heat should become more evenly distributed. This is very plainly manifested in the case of all manufactories where the firing is done at very high temperatures, and it would be quite safe

to say that china firing throughout the Staffordshire potteries is very much more uniformly accomplished than earthenware firing. It would seem as if at the high temperatures heat radiated much more rapidly, and tended to make the space much more uniformly heated; and I am assured that in regard to the hard-paste porcelain manufacture, instruments such as heat recorders would be of very little use, because when they have arrived at their normal firing point inequalities in different parts of the oven are scarcely known. In conclusion, I may sum up briefly by saying that, so far as I have gone in my experiments, I think I am justified in presuming that the contraction of a body such as that spoken of in this paper as a heat indicator, is within the range of possibilities, and, with further painstaking research, may become the most valuable of such instruments for pottery purposes." (*Trans. N.S.C.S.*, vol. ii. p. 92.)

Whenever the contraction or shrinkage under fire of clay compounds is used as a means of observing the heat attained, it must be borne in mind that the physical condition of the test-pieces has a very marked influence upon contraction.

This is demonstrated in a table (reprinted here by permission) used by Mr. Phillip Kirkup, of Cornsay Colliery, Co. Durham, in a paper he read before the Federated Institution of Mining Engineers, at Newcastle-on-Tyne, on the manufacture of fireclay goods.

Description of Clay.	Composition.		Degree of Fineness. Apertures per square inch of riddle.	Contraction between size when moulded and when burnt, per foot.
	Silica.	Alumina.		
	Per cent.	Per cent.		Inches.
Mild,	52	32	4	0·527
Do.	,,	,,	6	0·573
Do.	,,	,,	12	0·837
Do.	,,	,,	16	0·925
Strong,	62	25	4	0·275
Do.	,,	,,	6	0·454
Do.	,,	,,	12	0·605
Do.	,,	,,	16	0·734
Very strong,	85	8	4	0·063
Do.	,,	,,	6	0·324
Do.	,,	,,	12	0·459
Do.	,,	,,	16	0·486

(*British Clayworker*, August 1898, p. 141.)

Brongniart's or Sèvres Muffle-Kiln Pyrometer.—This is minutely described by Brongniart in the *Atlas* of his *Traité des Arts Céramiques*, p. 71, and carefully illustrated on plates lviii. and lxix. of that work.

It is also very fully illustrated and described in a publication entitled *Painting on Glass and Porcelain*, p. 251. (Published by Scott, Greenwood, & Co., of London.)

This is a pyrometer in which the expansion of a bar of metallic silver is the active force indicating the changes in temperature. As silver melts at 960° C., or nearly so, the range is limited, and its usefulness in ceramics is practically confined to the "hardening-on" and "enamel-colour kilns."

Seger "Cones."—"The most satisfactory method of gauging ceramic fires," writes Professor C. F. Binns, "is that introduced by Professors Seger and Cramer at Charlottenburg, and known as the '*normal pyrometric cones*.' The principle is that certain mixtures of clays and alkalies fuse at different points according to their composition. These mixtures are made into pyramids or cones, 6 centimetres high and $1\frac{1}{2}$ centimetres on each side of the triangular base. One of them is placed in the oven where it can be seen from outside, and when the point of the pyramid bends so far as to touch the base-level, the required temperature is reached." (*Ceramic Technology*, p. 59, Scott, Greenwood, & Co.)

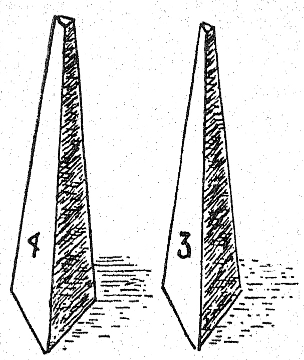


FIG. 173.—Seger cones.

Langenbeck relates how Dr. Heintz, following up the principle of Prinsep's melting pyroscopes, which were composed of metallic alloys (see *Philosophical Transactions*, 1828, p. 79), adopted glass mixtures on the type of porcelain glazes for the same purpose. (See *Thonindustrie Zeitung*, 1886, p. 135.) The solution of the collateral problem of increasing the range of these pyroscopes, and rendering them applicable to ceramic uses, was undertaken by Seger (see *Thonindustrie Zeitung*, 1886, pp. 135, 145, 168), and "He established that the most fusible mixture of the porcelain-glaze type was one of the chemical composition—

$$\left.\begin{matrix} 0{\cdot}3\ K_2O \\ 0{\cdot}7\ CaO \end{matrix}\right\} 0{\cdot}5\ Al_2O_3, 4SiO_2.$$

From this the more infusible glasses were obtained by the systematic increase of silica, with a proportional increase of alumina to correct the well-known tendency toward devitrification of highly siliceous glasses. By the partial substitution of alumina with ferric oxid the series was brought down in its member—

$$\left.\begin{matrix} 0{\cdot}3\ K_2O \\ 0{\cdot}7\ CaO \end{matrix}\right\} \left.\begin{matrix} 0{\cdot}3\ Al_2O_3 \\ 0{\cdot}2\ Fe_2O_3 \end{matrix}\right\} 4SiO_2$$

to equal the melting-point of the alloy 10 per cent. platinum, 90 per cent. gold, and thus became continuous with the most useful members of Prinsep's series. The use of the cones proved to be so practical for the purpose that

the need to substitute the Prinsep alloys by equivalent cones was soon felt; and E. Cramer, making use of the well-known fact that if the acidity of a glass be maintained, but the silica substituted by boracic acid, the melting-point is lowered, increased the series to begin with the melting-point of silver." (*Chemistry of Pottery*, p. 33, Chemical Publishing Co., Easton, Pa.)

From the lists of chemical composition, and estimated temperature of the melting-point of Seger "cones" given by Karl Langenbeck, the following have been selected as covering the range of heats usually employed in decorative-tile works:—

Cone Number.	Chemical Formulæ.	Estimated Temperature of Melting-point.
08	0·3 K_2O 0·2 Fe_2O_3 3·60 SiO_2 0·7 CaO 0·3 Al_2O_3 0·40 B_2O_3	998° C.
07	0·3 K_2O 0·2 Fe_2O_3 3·65 SiO_2 0·7 CaO 0·3 Al_2O_3 0·35 B_2O_3	1017° C.
06	0·3 K_2O 0·2 Fe_2O_3 3·70 SiO_2 0·7 CaO 0·3 Al_2O_3 0·30 B_2O_3	1036° C.
05	0·3 K_2O 0·2 Fe_2O_3 3·75 SiO_2 0·7 CaO 0·3 Al_2O_3 0·25 B_2O_3	1055° C.
04	0·3 K_2O 0·2 Fe_2O_3 3·80 SiO_2 0·7 CaO 0·3 Al_2O_3 0·20 B_2O_3	1074° C.
03	0·3 K_2O 0·2 Fe_2O_3 3·85 SiO_2 0·7 CaO 0·3 Al_2O_3 0·15 B_2O_3	1093° C.
02	0·3 K_2O 0·2 Fe_2O_3 3·90 SiO_2 0·7 CaO 0·3 Al_2O_3 0·10 B_2O_3	1112° C.
01	0·3 K_2O 0·2 Fe_2O_3 3·95 SiO_2 0·7 CaO 0·3 Al_2O_3 0·05 B_2O_3	1131° C.
1	0·3 K_2O 0·2 Fe_2O_3 0·7 CaO 0·3 Al_2O_3 4·0 SiO_2	1150° C.
2	0·3 K_2O 0·1 Fe_2O_3 0·7 CaO 0·4 Al_2O_3 4·0 SiO_2	1179° C.
3	0·3 K_2O 0·05 Fe_2O_3 0·7 CaO 0·45 Al_2O_3 4·0 SiO_2	1208° C.
4	0·3 K_2O 0·7 CaO 0·5 Al_2O_3 4·0 SiO_2	1237° C.
5	0·3 K_2O 0·7 CaO 0·5 Al_2O_3 5·0 SiO_2	1266° C.
6	0·3 K_2O 0·7 CaO 0·6 Al_2O_3 6·0 SiO_2	1295° C.
7	0·3 K_2O 0·7 CaO 0·7 Al_2O_3 7·0 SiO_2	1323° C.
8	0·3 K_2O 0·7 CaO 0·8 Al_2O_3 8·0 SiO_2	1352° C.

Langenbeck further explains that ". . . . the original series of Dr. Seger are made as follows :—The potash is taken in the form of orthoclase; the remaining alumina that is requisite is introduced in the form of kaolinite; and the remaining silica not supplied by these is added as quartz. Calcium carbonate gives the calcium oxid, and those needing ferric oxid have it directly added. The necessary amounts of these ingredients are weighed off for each number, introduced with water into a small porcelain-jar mill, thoroughly ground for half a day, settled, the water drawn off, and the mixture dried. It is then worked into a mass with dextrin mucilage, and formed into tetrahedrons six centimeters high and one and one-half centimeters on the sides of the triangular base." See *Thonindustrie Zeitung*, 1886, p. 136. (*Chemistry of Pottery*, p. 36, Chemical Pub. Co., Easton, Pa.)

Langenbeck suggests the following practical mixtures :—

FOR CONE NO. 1.

83·55 feldspar.
35·00 calcium carbonate.
66·00 quartz.
16·00 ferric oxide.

FOR CONE NO. 4.

83·55 feldspar.
35·00 calcium carbonate.
25·90 kaolinite.
54·00 quartz.

Professor Binns suggests the following :—

FOR A CONE TO BEND AT CHINA BISCUIT-OVEN HEAT.

85 feldspar.
35 whiting.
80 china-clay.
200 flint.

FOR A CONE TO BEND AT EARTHENWARE BISCUIT-OVEN HEAT.

85 feldspar.
35 whiting.
30 china-clay.
80 flint.

FOR A CONE TO BEND AT PRINTED GLOST-OVEN HEAT.

Fritt.

190 borax.
50 whiting.
50 china-clay.
95 flint.

Body Mixture.

33 fritt.
30 whiting.
50 feldspar.
10 china-clay.
60 flint.
15 ferric oxide.

Details of manufacture are given on pp. 62–63, *Ceramic Technology*.

Messrs. S. G. Bailey & Co., of Stroud, the agents for these pyroscopes in England, state that the cones are now in daily use by more than two hundred and fifty English houses. They explain that "In order to determine what cones are required . . . . to regulate the burning of any kind of goods, it is necessary for the first few times to place a few cones into the kiln or oven, surround them with bricks or a muffle, or some other arrangement which will keep them from being in contact with the flame, and then observe how they behave. If, for example, they exhibit the following appearance [*vide* fig. 174] the conclusion might be drawn that the temperature in the kiln agreed with

the melting-point of Cone No. 7, because Cone No. 6 is completely melted, whilst Cone No. 7 has bent over so that its apex tends to approach the base, and Cones Nos. 8 and 9 have remained erect with their edges sharply defined.

"Suppose it was found on examining the goods that the fire was stronger than usually desired, another experiment might be made with a few more cones melting at lower temperatures; for example, with Cones Nos. 4, 5, 6, and 7, in another kiln of goods, noting, if they come out of the desired quality, which cone melted. Having determined then what cone melts at the temperature which gives the desired quality in the goods, we have within our reach a means of regulating the temperature, and consequently the quality. We settle the right fire-temperature once for all, so that in all subsequent experiments three cones will generally suffice, and these should be chosen in such a way that the first announces by its melting the approach of the right temperature; in other words, it gives warning like a watchman. The melting of the second cone will then be watched with greater attention; whilst the third, indicating the attainment of the proper temperature, will bend over as regards its apex, and the edges will become somewhat rounded. . . . The cones are always to be placed in such a position within the kiln that, whilst they are exposed to the full heat, they do not encounter any live flame, whilst they should be plainly visible through a guarded aperture in the side of the kiln. . . . If these cones are exposed to live flame they naturally become twisted, and would indicate the wrong temperature."

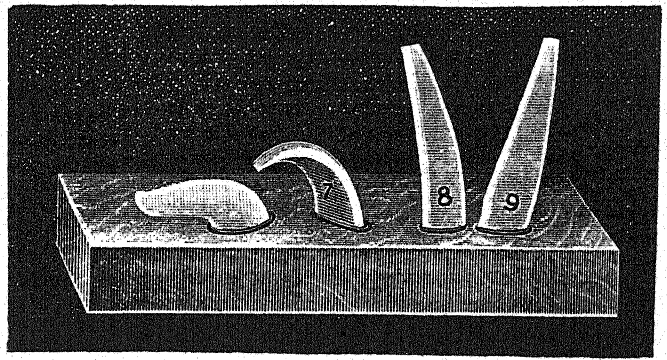


FIG. 174.—Seger cones in use.

Messrs. Pountney & Co., of Bristol, writing in 1898, say "It is a very easy matter to place these cones in a kiln so that they may be seen. We simply put a piece of mica in an iron frame, and insert this just over our trial-holes in the kiln; this practically forms a window through which you can see the action of the cones. We found no difficulty whatever in arranging this, and think the cones are of very great service in firing the oven." (*British Clayworker*, November 1898.)

The extensive use of these cones through Germany, Austria, France,

Great Britain, and the United States is evidence of their practical value; nevertheless, Seger cones are not absolutely perfect pyrometers. Professor Binns wrote:—" In firing an oven repeatedly week after week, it is not possible under the present system to secure absolute uniformity, and therefore a cone which appears satisfactory one week will seem too soft or too hard the next." (*Ceramic Technology*, pp. 59, 60, Scott, Greenwood, & Co.)

Again, a correspondent in the *British Clayworker*, August 1898, wrote:—" In several instances the one supposed to be more easily fusible than the other has stood longest, and still more often what appeared to be a perfect cone, looked at through the inspection-hole, has turned out to be nothing but the shell of the cone, the inside having fused and run out at the bottom."

Others have complained of the difficulty of clearly observing in a series which cone had bent or melted, and which had not; and on three occasions the shortcomings of Seger cones have been discussed by the American Ceramic Society, and Professor Orton and others have made numerous attempts at remedying these deficiencies.

Still, the cones are acknowledged to be of great practical and scientific utility, and Professor E. Orton, jun., who is the largest manufacturer of pyrometric cones in the United States of America—his sales in the year 1902 being 440,000 cones—states that they are made by exactly the same formulæ as the German "Seger" cones, and are intended to be in all respects the same. He views them in the light of a scientific discovery of exceeding importance to the ceramic industry; in respect of which he says:—" Dr. Seger did all of the important technical work in developing the cone system, and his should be the glory eternal. The rest of us have simply made a commercial success of something which his brain devised. We may perhaps have improved it in small respects, but nothing fundamental."

Respecting the actual batch-weights of ingredients used in the making of pyrometric cones, Professor Orton refers to those published by Dr. Post as the theoretical batch-weights which all conemakers use, whether German, English, or American; but adds significantly:—" We cannot depend on the batch-weights to give us a perfect cone. For instance, I make up my number 4 cone according to the theoretical batch-weights. Then I test it, and always find it a little too hard or a little too soft, depending on the quality of the crude mineral supply that I happened to be using at the time. Then I add to it a little more flux or a little more hardening matter, and grind it, and resample and retest it, so that I arrive by gradual approximations to the point where the cone melts, identically with the standard which I keep for testing purposes only. In order to prevent irregularities in my materials creeping in gradually, I keep in hand a number of thousands of cones for testing purposes alone. I have prepared a sufficient number to last twenty years, and no sales are ever made from these test batches under

any consideration. By this means I hope to maintain uniformity as long as I am in the business."

The following are the batch-weights and formulæ for Standard Cones Nos. 1 to 6 given by Dr. Seger. (*Seger's Collected Writings*, p. 191.)

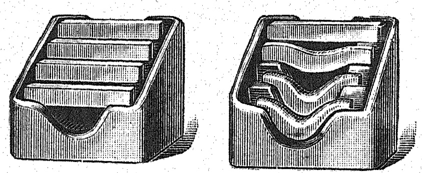
1	$\left.\begin{matrix}0{\cdot}3\ K_2O \\ 0{\cdot}7\ CaO\end{matrix}\right\} \left\{\begin{matrix}0{\cdot}2\ Fe_2O_3 \\ 0{\cdot}3\ Al_2O_3\end{matrix}\right\} 4SiO_2$	Feldspar, Marble, Quartz, Iron oxide,	83·55 35·00 66·00 16·00
2	$\left.\begin{matrix}0{\cdot}3\ K_2O \\ 0{\cdot}7\ CaO\end{matrix}\right\} \left\{\begin{matrix}0{\cdot}1\ Fe_2O_3 \\ 0{\cdot}4\ Al_2O_3\end{matrix}\right\} 4SiO_2$	Feldspar, Marble, Quartz, Iron oxide, Zettlitz kaolin,	83·55 35·00 60·00 8·00 12·95
3	$\left.\begin{matrix}0{\cdot}3\ K_2O \\ 0{\cdot}7\ CaO\end{matrix}\right\} \left\{\begin{matrix}0{\cdot}05\ Fe_2O_3 \\ 0{\cdot}45\ Al_2O_3\end{matrix}\right\} 4SiO_2$	Feldspar, Marble, Quartz, Iron oxide, Zettlitz kaolin,	83·55 35·00 57·00 4·00 19·43
4	$\left.\begin{matrix}0{\cdot}3\ K_2O \\ 0{\cdot}7\ CaO\end{matrix}\right\} 0{\cdot}5\ Al_2O_3,4SiO_2$	Feldspar, Marble, Quartz, Zettlitz kaolin,	83·55 35·00 54·00 25·90
5	$\left.\begin{matrix}0{\cdot}3\ K_2O \\ 0{\cdot}7\ CaO\end{matrix}\right\} 0{\cdot}5\ Al_2O_3,5SiO_2$	Feldspar, Marble, Quartz, Zettlitz kaolin,	83·55 35·00 84·00 25·90
6	$\left.\begin{matrix}0{\cdot}3\ K_2O \\ 0{\cdot}7\ CaO\end{matrix}\right\} 0{\cdot}6\ Al_2O_3.6SiO_2$	Feldspar, Marble, Quartz, Zettlitz kaolin,	83·55 35·00 108·00 38·85

Holdcroft & Co.'s Thermoscope.—One of the most practical and well-conceived attempts at improvement upon Seger cones, following closely in the same path, is the thermoscope invented and patented by Messrs. Holdcroft & Co., of Tunstall, in the year 1898—Pat. No. 8426.

This improvement consists principally of a rearrangement of the apparatus in a more practically useful form. Instead of tetrahedrons or trihedral pyramids such as Seger cones, rectangular bars are used, about $2\frac{1}{2}$ inches long, having a thickness of section of about $\frac{1}{3}$-inch by $\frac{1}{3}$-inch.

The compositions of which the bars are formed are varied according to the temperature at which they are required to soften, in such a manner as to furnish a long series of bars capable of indicating temperatures from dull red

to dazzling white heat. They are numbered beginning with No. 1, the most fusible, and diminishing in fusibility at about the same rate as Seger cones. Instead of being hardened imperfectly by dextrine, they are baked to a temperature sufficient to induce incipient vitrification, and thus render them tolerably safe for transit. When in use the numbered bars are placed horizontally on small fireclay stands, specially made and formed in the shape of a miniature pair of four-tread stairs, the intermediate space being deeply recessed, so that only the ends of the bars are supported when placed in position on the special stands.



Before using. After using.

FIG. 175.—Holdcroft's thermoscope.

The contact faces of these fireclay stands are washed with ground calcined-flint slip before the bars are placed upon them, so as to prevent permanent adhesion after use, and to enable the same stands to be used repeatedly. A suitable series of bars having been laid on, one such stand is placed in each trial saggar of an oven, or in any position in a muffle-kiln conveniently observed from without, a mica window intervening.

Messrs. Holdcroft & Co.'s instructions read as follows:—"When first using the THERMOSCOPE, it is necessary to determine which bar has the melting-point of the oven or kiln in question. This may be done by introducing a range of bars on two or more stands into the trial saggar: the range required may be judged from particulars which follow. When the stand comes from the oven after firing, it is observed which is the highest numbered bar that is bent in the middle—the next higher remaining quite straight. Say this number is 22. If the ware is perfectly fired the stand must in the future contain the same number, 22, and one higher—to indicate if the temperature has risen too high; and, say, two lower, 21 and 20—to act as warnings to the fireman of the approach of the proper temperature.

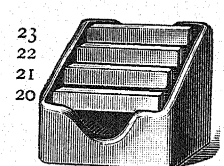


FIG. 176.—Before using.

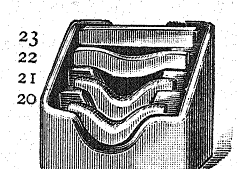


FIG. 177.—After using.

"The stand having been placed in the trial saggar, or opposite the trial hole, the fireman observes the droop first of 20, then of 21. These act as warnings or indications of the approaching droop of 22, when the oven is perfectly fired. Number 23 must remain unbent.

"In this way it is easily possible to control and regulate the temperatures within 10 or 20° F., and uniform results can be ensured. Not only is spoilt ware diminished in amount or abolished altogether, but the quality is improved both as regards the regularity of tint and brightness of glaze, while great economy of fuel results from the absence of over-firing.

"In other kilns or ovens bars of greater or less fusibility would be used, as was found to be necessary, but one and the same method is applicable to all cases.

"The following are approximately the ranges within which will be found the bar melting in the given ovens and kilns:—

Enamel kilns,	39
Tiles and red bricks,	17–22
Majolica,	15–22
Fireclay goods,	23–32
Glost ovens,	19–25
Earthenware biscuit,	23–29
China biscuit,	28–32

"Owing to the uncertainties in determinations of high temperatures, no accurate figures can be given for the melting-points of various bars. Approximations can, however, be obtained by comparisons of the melting-points of various metals and of the bars.

"Thus 13 melts at the same temperature as silver.
19 " " " gold.
23 " " " alloy 9 gold, 1 platinum.

"These temperatures have been approximately determined, and may be stated as 1750° F., 1967° F., and 2073° F., respectively.

"The bars after having been melted may be easily detached from the fireclay stands if the precaution is taken of coating with slop flint such parts of the surface of the stand as will come into contact with the fused material. A slight tap is sufficient to remove them; and the same stand can be used an indefinite number of times.

TABLE OF APPROXIMATE BENDING TEMPERATURES FOR HOLDCROFT & CO.'S THERMOSCOPE.

No.	Fahr.	Cent.	No.	Fahr.	Cent.	No.	Fahr.	Cent.
1	1029	554	12	1701	928	23	2073	1134
2	1090	588	13	1763	962	24	2140	1171
3	1151	622	14	1793	979	25	2197	1208
4	1212	656	15	1823	996	26	2272	1245
5	1273	690	16	1854	1013	27	2339	1282
6	1334	724	17	1885	1030	28	2407	1320
7	1395	758	18	1916	1047	29	2475	1358
8	1456	792	19	1947	1064	30	2545	1396
9	1517	826	20	1978	1081	31	2613	1434
10	1578	860	21	2010	1099	32	2682	1472
11	1639	894	22	2041	1119	33	2750	1510

A rather different range of the bars required for specified fires is given

by Mr. Jackson, which we reprint below from *Pottery Gazette*, August 1903, p. 807.

Enamel kiln,	Nos. 4– 8
Majolica glaze,	Nos. 17–22
Earthenware glaze,	Nos. 20–24
Earthenware biscuit,	Nos. 24–29
English china glaze,	Nos. 20–24
English china biscuit,	Nos. 27–31
Red bricks and tiles,	Nos. 20–24
Firebricks, etc.,	Nos. 26–30

Watkin's Patent Heat Recorders.—The property of progressive variation of melting temperature of equivalently varied ceramic compositions was further utilized by Mr. Henry Watkin, of Burslem, in connection with an instrument he has invented, and has chosen to designate a "heat recorder." This instrument is simply a small oblong block of baked refractory composition measuring 50 mm. by 12½ mm. by 10 mm., having five circular recesses sunk into it from the top. In the recesses are placed pellets of fusible ceramic compositions of known melting-point.

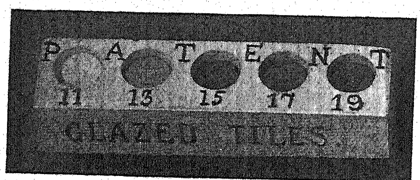


FIG. 178.—Watkin's heat recorder for glaze kilns.

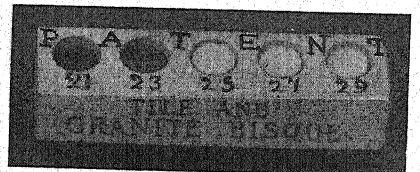


FIG. 179.—Watkin's heat recorder for biscuit ovens.

The blocks are marked and numbered for identification before and after use. When put into use they are placed in any parts of the ovens or kilns of which it is required to ascertain the temperature attained, or other things deducible from the effect upon the pellets. In the course of the burning some pellets may melt down, others become more or less rounded on the edges, and others may resist the fire and conditions altogether.

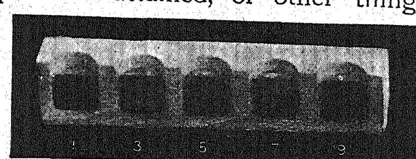


FIG. 180.—Section before firing.

To read off and register the results, when the recorders have been withdrawn from the oven or kiln along with the wares, after burning and cooling is complete, it is only necessary to note which pellet has become slightly rounded on the edge, as No. 7 in fig. 181, and register the number of that pellet only as the one attained, dis-

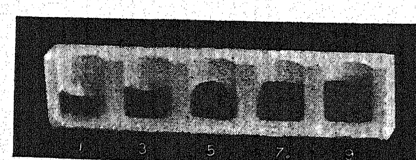


FIG. 181.—Section after firing.

regarding both those that have completely melted down and those remaining refractory.

In one of the pamphlets which Mr. Watkin has published explaining these matters, he suggests a convenient form of register which will probably be found useful to all who wish to study systematically what occurs within the kilns during firing. The object of using these recorders is not to act as guides for judging the progress of the burning while it is actually being effected, but rather to serve as an automatic "tell-tale" within the kiln, recording the highest temperature attained in any particular part; so that, afterwards, the register of the whole of the records may be studied in conjunction with wares drawn from the oven or kiln, with a view to acquiring more accurate knowledge of the best conditions of burning for future guidance.

For experimental work, and for quickly discovering the most suitable recorder for use in any particular kiln, or part of a kiln, Mr. Watkin has prepared an arrangement of pellets which he calls a DISCOVERER (fig. 182).

The one illustrated has a range of 680° C., and will indicate within 20° C. the heat attained in any enamel kiln, glaze kiln, or English glost oven. Others of higher ranges are also manufactured.

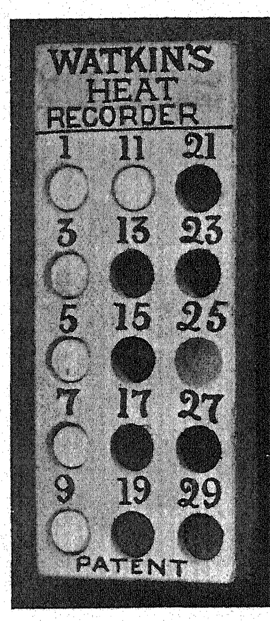


FIG. 182.—Watkin's discoverer. 1–29; 590° C.–1270° C.; 1094° F.–2318° F.

Mr. Watkin regulates the composition of and numbers the pellets in such a manner that the temperature at which their edges merely become rounded compares with ordinary pyrometric standards in the relation shown by the following copyright table, which is reprinted here by Mr. Watkin's special permission:—

TABLE OF TEMPERATURES OF THE MELTING-POINTS OF THE RECORDERS.

Numbers.		Cent.	Fahr.	Numbers.		Cent.	Fahr.	Numbers.		Cent.	Fahr.
Watkin.	Seger.			Watkin.	Seger.			Watkin.	Seger.		
1	022	590	1094	11	012	890	1634	21	02	1110	2030
2	021	620	1148	12	011	920	1688	22	01	1130	2066
3	020	650	1202	13	010	950	1742	23	1	1150	2102
4	019	680	1256	14	09	970	1778	24	2	1170	2138
5	018	710	1310	15	08	990	1814	25	3	1190	2174
6	017	740	1364	16	07	1010	1850	26	4	1210	2210
7	016	770	1418	17	06	1030	1886	27	5	1230	2246
8	015	800	1472	18	05	1050	1922	28	6	1250	2282
9	014	830	1526	19	04	1070	1958	29	7	1270	2318
10	013	860	1580	20	03	1090	1994	30	8	1290	2354

TABLE OF TEMPERATURES OF THE MELTING-POINTS OF THE RECORDERS—*continued.*

Numbers.		Cent.	Fahr.	Numbers.		Cent.	Fahr.	Numbers.		Cent.	Fahr.
Watkin.	Seger.			Watkin.	Seger.			Watkin.	Seger.		
31	9	1310	2390	41	19	1510	2750	51	29	1710	3110
32	10	1330	2426	42	20	1530	2786	52	30	1730	3146
33	11	1350	2462	43	21	1550	2822	53	31	1750	3182
34	12	1370	2498	44	22	1570	2858	54	32	1770	3218
35	13	1390	2534	45	23	1590	2894	55	33	1790	3254
36	14	1410	2570	46	24	1610	2930	56	34	1810	3290
37	15	1430	2606	47	25	1630	2966	57	35	1830	332[illegible]
38	16	1450	2642	48	26	1650	3002	58	36	1850	3362
39	17	1470	2678	49	27	1670	3038	59	37	1870	3398
40	18	1490	2714	50	28	1690	3074	60	38	1890	3434

By the aid of this instrument the effect of different intensities of heat upon several clays and bodies were observed and recorded, and from Mr. Watkin's copyright tables of such records, by special permission, the following have been derived :—

EFFECT OF VARYING DEGREES OF FIRE ON NATURAL CLAYS.

Clay.	Percentage Contraction.					Percentage Loss in Weight.				Percentage Porosity.				Sp. Gr.	
	White, Dry.	Recorder No.				Recorder No.				Recorder No.				Recorder No.	
		8.	15.	22.	29.	8.	15.	22.	29.	15.	22.	29.	33.	15.	29.
Yellow marl,	4	4	6	11	12	5·5	6·9	8·5	8·6	13·9	6·3	1·2	·6	2·59	2·32
Red marl,	3	3	3	6	7	6·0	8·4	8·4	8·4	11·9	8·5	6·7	1·80	2·74	2·63
Saggar marl,	2	2	2	5	7	6·0	7·7	7·6	7·7	15·1	10·3	4·1	·60	2·64	2·46
Ball-clay, North Devon,	2	2	3	8	9	6·8	9·2	9·6	9·6	15·7	·00	·00	·00	2·50	2·36
,, B.S.W. black,	4	4	7	11	11	8·8	12·0	12·3	14·6	12·3	·00	·33	·00	2·62	2·53
,, D.T.,	2	2	3	10	10½	10·7	12·8	14·5	11·6	22·2	8·4	·08	·18	2·66	2·50
,, D. black,	2	2	4	10	11	10·2	12·5	12·4	12·9	24·4	6·6	·11	·08	2·82	2·48
,, H. blue,	2	2	4	11	11	10·6	13·6	14·0	14·1	23·7	0·9	·39	·13	2·65	2·49
,, B. blue,	2	2	4	9	10	8·8	10·7	10·6	10·7	19·8	7·9	2·3	·03	2·66	2·55

It is not stated what mesh sieves were used to pass the clay-slips through in the course of preparing the test-pieces ; nor the precise condition or state of dryness which was taken as the basis or starting-point for the observations ; and Mr. Watkin does not explain whether the test-pieces were formed by slip-casting, plastic-pressing, or dust-pressing. Nor yet, again, is it stated whether the observations apply to oxidizing, reducing, or alternating kiln-atmospheres. These are all powerful factors which of necessity would have to be ascertained and checked before the tables could be used for scientific determinations.

Nevertheless the tables are particularly instructive, and Mr. Watkin must have expended much time and labour in making the trials, and so minutely

registering and tabulating the results. They show what a wide field still remains for the enquirer, and how greatly this system of investigation could be extended.

But even the same native clay may itself vary in chemical and physical composition, and compounded bodies too. These variations might bring about changes in test-results which would perturb the records, so that, before any general conclusions could be deduced, confirmatory observations or "control experiments" would be necessary.

A cursory glance at the tables appears to indicate that the combined water is expelled distinctly earlier than either contraction or change of porosity set in; also that contraction and vitrifaction occur, with each of the materials tested, at some temperature or condition of heat between 15 (=990° C.) and 29 (=1270° C.). In the case of the body-tests in the following table, which also is reprinted here with Mr. Watkin's special permission, the vitrifaction points are clearly shown to be, for the particular bodies he tested, thus:—China body, 1190° C.; white body, 1170–1190° C.; ivory body, 1170–1190° C.; mortar body, 1110° C.; insulator body, 1110° C.; red body, about 1350° C.; and few practical potters will deny that these figures are somewhat surprising.

The phenomenon of similarity of specific gravity and the comparative regularity of variation of specific gravity of the materials under fire is very forcibly exemplified in Mr. Watkin's instructive tables; all the clays shown, except the one impregnated with ferric oxide, approximating remarkably to sp. gr. 2·6 after subjection to a temperature of about 990° C., and to sp. gr. 2·5 after heating to about 1270° C.

PERCENTAGE CONTRACTION, POROSITY, AND LOSS OF WEIGHT OF SIX DIFFERENT BODIES AT VARYING DEGREES OF TEMPERATURE.

Recorder Nos., . .	20.	21.	23.	25.	29.	31.
CHINA BODY—						
Contraction, ...	2·0	3·4	7·25	9·67	10·15	8·75
Porosity, ...	19·28	8·70	5·07	·06	·07	·10
Loss in weight, . . .	25·79	25·85	26·40	26·01	26·09	26·14
WHITE BODY—						
Contraction, ...	3·80	5·50	5·82	6·00	8·00	8·00
Porosity, ...	12·78	8·73	6·59	·00	·01	·00
Loss in weight, . . .	22·70	22·69	22·46	22·50	22·88	22·71
IVORY BODY—						
Contraction, ...	5·3	6·02	6·0	6·75	7·77	7·67
Porosity, ...	10·04	6·19	3·53	·00	·03	·04
Loss in weight, . . .	21·20	21·24	20·13	21·21	21·71	21·44
MORTAR BODY—						
Contraction, ...	5·0	6·55	6·72	7·1	5·85	6·7
Porosity, ...	6·35	·03	·00	·00	·01	·03
Loss in weight, . . .	20·33	20·67	20·59	20·40	20·52	20·55

PERCENTAGE CONTRACTION, POROSITY, AND LOSS OF WEIGHT OF SIX DIFFERENT BODIES AT VARYING DEGREES OF TEMPERATURE—*continued.*

Recorder Nos., . .	20.	21.	23.	25.	29.	31.
INSULATOR BODY—						
Contraction, ...	5·8	7·4	7·62	8·25	6·8	5·5
Porosity, ...	5·56	·01	·00	·07	·00	·00
Loss in weight, . . .	21·55	21·86	22·15	22·04	21·54	22·00
RED BODY—						
Contraction, ...	6·5	6·7	6·37	6·4	8·0	8·5
Porosity, ...	7·40	6·52	5·14	1·09	·86	·30
Loss in weight, . . .	20·80	20·99	20·40	21·19	21·05	20·96

N.B.—Other bodies would behave in a similar manner, but the figures would probably differ from these.

"**A.B.C." Pyro-Indicators.**—While compiling these notes, a simple method of checking the results of ceramic firing, when the wares are being "drawn" from the ovens or kilns, has occurred to the writer; namely, the use of what may be provisionally termed "A.B.C." ceramic pyro-indicators: that is to say, a series of small capital letters of the English alphabet formed of precisely such compositions as are used in the preparation of Seger's normal pyrometric cones—each similar character invariably to be made of a certain composition having a definite melting-point, and every different letter to be of a different compound arranged in progressive series in alphabetical sequence, the series by preference to begin at the equivalent of Seger Cone 018, or approximately 710° C., this being **A**; and afterwards following the sequence of Seger cones up to Cone 8, or approximately 1290° C., which will be **Z**. See the following table of rough comparisons of the several systems now in general use.

The manufacturer, having ascertained by actual experiment what particular heat it is most desirable that his wares shall attain during burning, selects the corresponding letter of the "A.B.C." series. One of these little letter telltales should then be placed on some convenient projection or setter near the top of *every* saggar of ware before it is set in the oven, so that, when the saggar is "drawn" after the ware has been fired, the letter will immediately be seen *without disturbing the ware.* When the oven is being "drawn," the foreman can then see instantly whether the "A.B.C." pyro-indicator letter adheres or not, and may either pass the ware as satisfactory, or, without hesitation or expense of sorting or replacing, have the whole saggarful of ware put aside for refiring. This will preclude the possibility of any seriously short-fired wares passing into the warehouses from any part of the ovens whatever.

The use of this system in conjunction with Holdcroft & Co.'s thermoscope or Seger cones should carry certainty in burning just another stage nearer scientific accuracy.

The system is perfectly free for the unrestricted use of the industry, without let or hindrance. It is not really necessary even to go to the expense of forming the test-mixtures into alphabetical shapes; each manufacturer may, when once he has learned the composition of a mixture most suitable to his own particular class of ware, simply form it into little wafers, and distinguish those for "biscuit," "glost," "enamel," etc., kilns in any way that suggests itself, either by vegetable colours, or by shapes such as squares, triangles, discs, etc. Nor, perhaps, need he follow the compositions given in the foregoing notes, but by a few careful and repeated experiments each manufacturer may prepare, for his own use, test-mixtures, say, of ball-clay, felspar, whitening, and flint; or ball-clay, felspar, flint, and leadless glaze.

One request, however, it is desirable to make, namely, that whoever chooses to form the compounds into alphabetical shapes will conform approximately to the series of equivalent temperatures indicated in the following table of comparisons: the ceramic letter "**A**" melting or considerably softening at 710° C., "**B**" at 740° C., and so on.

ROUGH COMPARISON OF SEVERAL CERAMIC PYROMETRIC SYSTEMS.

Seger Cones.	Holdcroft's Thermoscope Bars.		Watkin's Heat Recorders.	A.B.C. Ceramic Pyro-indicators.	Centi-grade.	Fahr.	Pouillet's Heat Colour Table.	Ovens and Kilns Range of Heat.							
	No.	Approx. Temp.	No.					China Enamel Colours.	Hard Kiln Maroon, etc.	Majolica Glaze Kiln.	Rock. and Easy E.W. Glost Oven.	Printed E.W. Glost Oven.	E.W. Biscuit Oven.	Tile Biscuit Oven.	Bone-China Biscuit Oven.
018	5	(690° C.)	5	**A**	710°	1310°	Dull red								
017	6	(724° C.)	6	**B**	740°	1364°									
016	7	(758° C.)	7	**C**	770°	1418°	Incipient cherry								
015	8	(790° C.)	8	**D**	800°	1472°									
014	9	(826° C.)	9	**E**	830°	1526°									
013	10	(860° C.)	10	**F**	860°	1580°									
012	11	(894° C.)	11	**G**	890°	1634°									
011	12	(928° C.)	12	**H**	920°	1688°	Cherry, 900° C.								
010	13	(962° C.)	13	**I**	950°	1742°									
09	14	(979° C.)	14	**J**	970°	1778°									
08	15	(996° C.)	15	**K**	990°	1814°									
07	16	(1013° C.)	16	**L**	1010°	1850°	Clear cherry, 1000° C.								
06	17	(1030° C.)	17	**M**	1030°	1886°									
05	18	(1047° C.)	18	**N**	1050°	1922°									
04	19	(1064° C.)	19	**O**	1070°	1958°									
03	20	(1082° C.)	20	**P**	1090°	1994°									
02	21	(1099° C.)	21	**Q**	1110°	2030°	Dull orange, 1100° C.								
01	22	(1119° C.)	22	**R**	1130°	2066°									
1	23	(1134° C.)	23	**S**	1150°	2102°									
2	24	(1171° C.)	24	**T**	1170°	2138°									
3	...		25	**U**	1190°	2174°									
4	25	(1208° C.)	26	**V**	1210°	2210°	Clear orange, 1200° C.								
5	26	(1245° C.)	27	**W**	1230°	2246°									
6	...		28	**X**	1250°	2282°									
7	27	(1282° C.)	29	**Y**	1270°	2318°									
8	28	(1320° C.)	30	**Z**	1290°	2354°	White, 1300° C.								

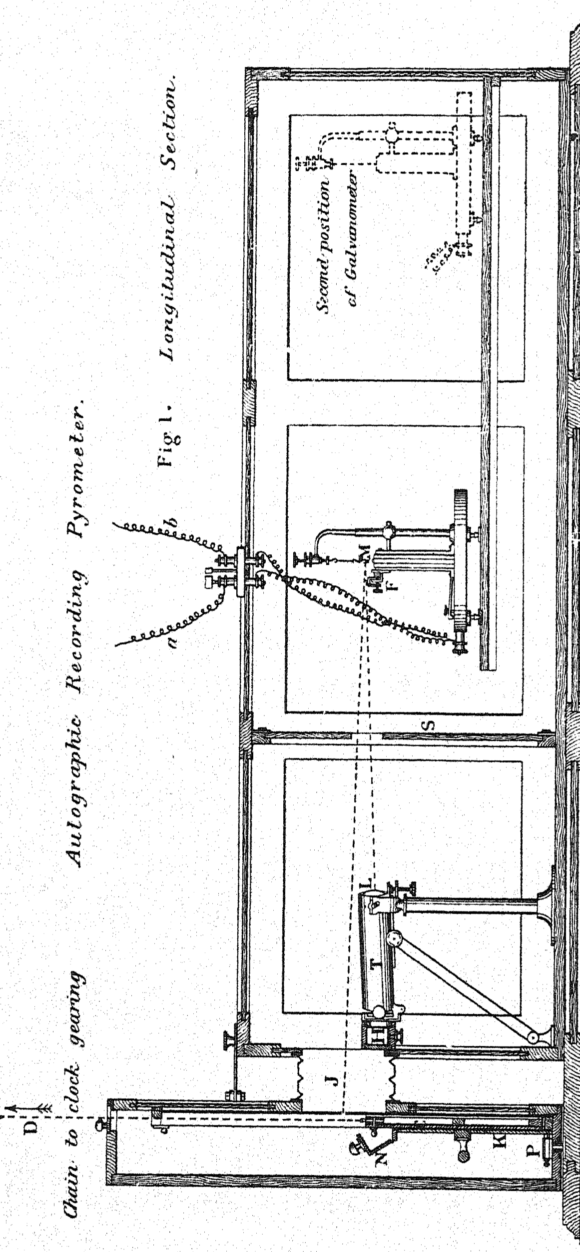


FIG. 183.—Professor Sir W. Chandler Roberts-Austen's recording pyrometer.

Professor Sir W. C. Roberts-Austen's Electrical Pyrometer.—The *British Clayworker* of July 1895 contains a description of this instrument by the distinguished inventor himself, who, after some introductory remarks, writes as follows:—"What is really wanted is some form of recording pyrometer, and this has comparatively recently been placed at the disposal of manufacturers by the writer of the present article. The actual method of measuring the temperature is simple in the extreme, and may be made clear by the following illustration. Take a thin wire of iron and another of platinum. Twist their ends together, and connect their free ends with a galvanometer which is capable of indicating the strength of an electric current passing through it. Now heat the twisted junction of the iron and platinum wires. This junction forms a battery which is 'excited,' to use popular language, by the application of heat. Even holding the junction between the fingers will generate an electric current, and so, of course, will heating the junction by a flame, or placing it in a hot receptacle. The strength of the current generated can be measured by the amount of deflection of the

galvanometer mirrors, and the strength of the current is found to be proportional to the temperature to which the little junction of the two different wires is raised. The junction is therefore called a 'thermo-junction,' and it is better to use, instead of a wire of platinum joined to one of iron, one of platinum joined to another wire of platinum which is not pure, but admixed with either rhodium or iridium.

"The method of measuring the high temperatures remains to be considered. As shown in figs. 1 and 2 [figs. 183 and 184], the appliance consists of a camera about five feet long, in which the galvanometer may be placed in either of two positions, according to the range of temperature to be observed; the nearer position is for observing large ranges, and the further for small ranges. This camera has three doors, and is made separate from the portion of the apparatus which contains the moving photographic plate. The two parts are connected by a flexible leather 'bellows' junction J, the object being to enable the plane of the sensitized plate to be adjusted at right angles to the ray of light from the stationary galvanometer mirror F. Inside the camera is a focussing tube T, containing a lens L, which receives the light from the mirror H, and transmits it to the galvanometer mirrors F and M. Of these mirrors, M is moveable and is carried by the coil of the galvanometer; while F is stationary on an adjustable arm fixed to the supports of that instrument, its function being to send a ray of light from the mirror H to the slit A B [fig. 184], and thus to trace a datum line as the photographic plate travels upwards. The temperature is recorded by the variations in the position of the spot of light derived from the moveable mirror M.

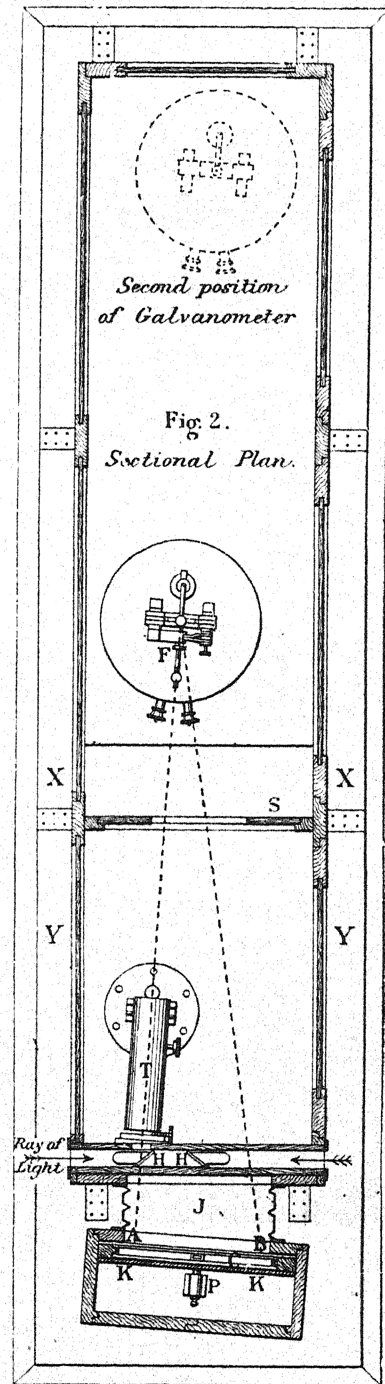


FIG. 184.—Professor Sir W. C. Roberts-Austen's recording pyrometer.

There is a screen S to cut off light reflected from the brasswork of the galvanometer. The end of the tube T is providable with an adjustable brass slit, by means of which the width of the photographic traces on the plate can be varied. The mirror H is mounted on a block, which can be adjusted so that external light may be brought from either side. The focussing lens L may be effected from outside the camera. Plug connections are provided at the top of the instrument, and the wires *a b* connect the galvanometer with the thermo-junction at the source of heat. The photographic plate is secured to its carrying slide C (fig. 2 [fig. 184]) by means of little cams, and the carrier C is enclosed in a case K, provided with a light-tight door N. The case K is held in position by a pin P. The connection of the photographic plate with the driving clock is shown at D (fig. 1 [fig. 183]). The sensitized plate moves

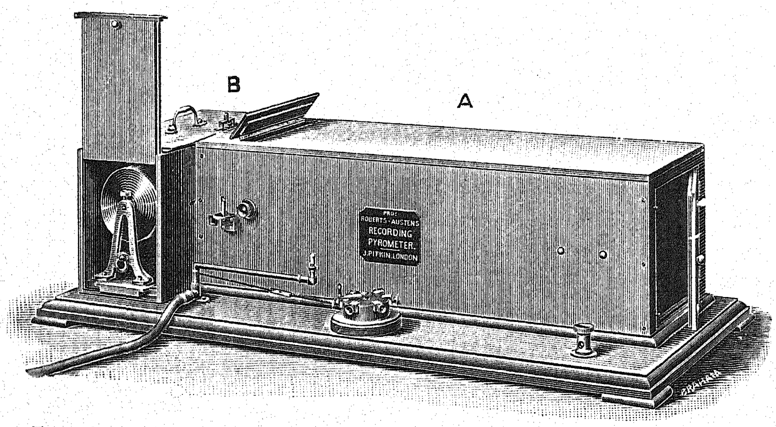


FIG. 185.—Pitkin's form of the recording electrical pyrometer of Sir W. Chandler Roberts-Austen, K.C.B., F.R.S.

in front of the slit A B and is lifted by a weight actuating a fine clock. Such a form of appliance is used for delicate work.

"For industrial use the simpler appliance (this is made by Mr. Pitkin, of Red Lion Street, Clerkenwell) shown in fig. 185 is employed. The principle on which it works is, however, the same, but a revolving drum, actuated by clockwork, replaces the moving plate of the more elaborate apparatus. Round this drum the sensitized paper is wound. A suitable switch enables six or more furnaces to be connected with the recorder at the will of the operator. . . .

"Two thermo-couples might be introduced into the kiln. One thermo-couple would be connected with platinum-wire leads, twelve feet long, lying along the bottom of the kiln, a hole being bored by the side of one of the fire-holes to allow of the couple being inserted. The other couple, also with platinum leads twelve feet long, could be inserted through the doorway, and

supported horizontally by the 'gear of the kiln.' In the case of salt-glaze kilns the platinum wire needs careful protection from the fumes. These, therefore, should be threaded through double-holed fireclay piping, and enclosed in earthenware tubes luted with clay at the joints and end. The wires will be found to stand the heat very well, and may easily be withdrawn at the end of the burning. . . . . The recorder, working day and night, would show not only the actual temperature at any given time, but also the rate of firing. For instance, if the burner, instead of making up his fires every hour, did so every two hours, the heat gained by the kiln from the combustion of the coal when 'making up' would be lost during those two hours, since the heat remains practically the same all through the night, thereby delaying the 'burning off' of the kiln.

"Any number of kilns might be connected with the recorder, and by means of an automatic switch the temperature of, say, six kilns may be recorded practically simultaneously. By use of the recording pyrometer, the amount of coal consumed may be decreased, the heating and cooling of the kilns is regulated with certainty, and a check kept on the burner. The cost of such an installation would vary from £50 to £80, according to the number of kilns fitted. The introduction of the appliance into ironworks has been attended with remarkable success. . . . . The first potteries in which the recorder has been used are those of Sir Henry Doulton at Lambeth."

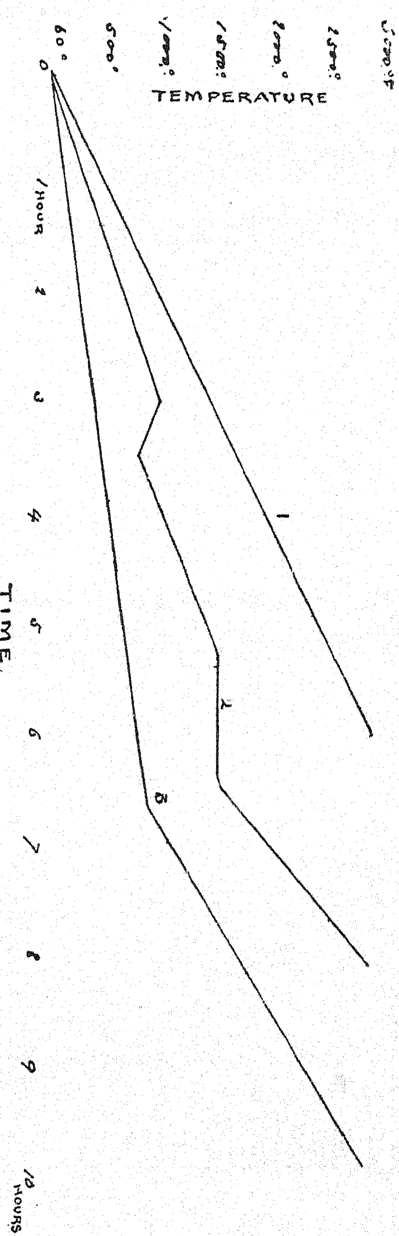


FIG. 186.—Diagram.

Respecting the diagram fig. 4 (fig. 186), Sir Roberts-Austen writes:—"In the diagram the horizontal line at the base marked 'time' is divided into hours, and the vertical line into temperatures. The line representing record No. 1 would

indicate the perfect firing of a kiln actually used, it may be added, in the preparation of electric-light carbons. The temperature, it will be seen, has been gradually raised in six hours from the ordinary temperature of the air, 60° Fahr., to a temperature of 3000° Fahr. No. 2 record, on the

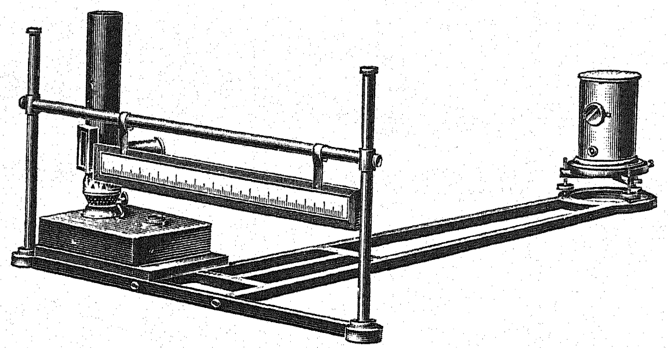


FIG. 187.—Pitkin's indicating pattern, no record, reading up to 3000° F.

other hand, shows that a temperature of 1000° was attained in three hours, but that, from some cause or other, the temperature fell, there being a second phase of irregular heating between the fifth and seventh hours. Record No. 3 shows that a temperature of 1000° was slowly attained in six and a half hours, and that a subsequent rise in temperature was more rapidly effected. These curves, however, merely indicate the kind of information which may be afforded." (*British Clay-worker*, July 1895, pp. 88–90.)

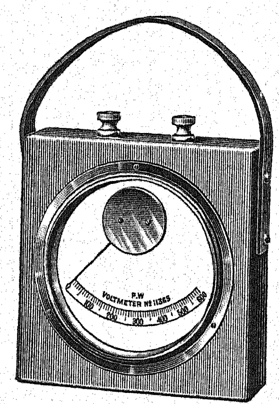


FIG. 188.—Pitkin's portable pyrometer, reading up to 3000° F.

In addition to the recording pattern, Messrs. James Pitkin & Co. have recently put on the market an indicating and also a portable pyrometer. The indicating pattern (fig. 187) consists of a sensitive dead-beat galvanometer, used with a scale and lamp-stand. This latter may be paraffin, gas, or electric light. It can be used in daylight, the scale being transparent, and the reading taken by looking through the scale towards the galvanometer.

The portable pattern (fig. 188) is also a useful instrument. It is sent out calibrated and ready for immediate use. The dial is about 6 inches diameter, and the scale is open. A portable thermo-junction is supplied (fig. 189). Any of the three patterns can be used as far as half a mile from the kiln or furnace or source of heat, when suitable provision is made for doing so.

The cost of the two last-mentioned patterns is considerably less than the recording type.

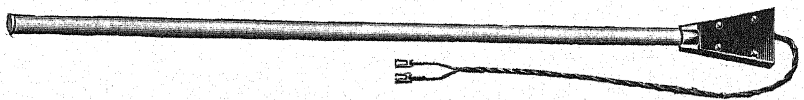


FIG. 189.—Pitkin's portable thermo-junction.

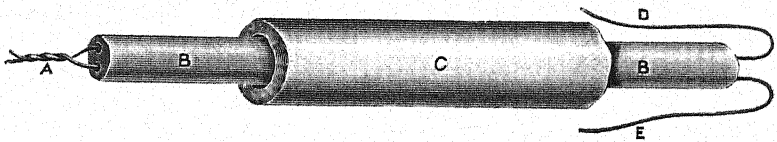


FIG. 190.—Pitkin's thermo-junction.

Two recently introduced forms of electrical pyrometer for industrial purposes are the office pyrometer (fig. 191) and the works pyrometer (fig. 192).

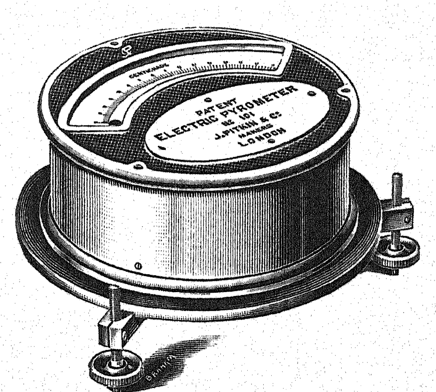


FIG. 191.—Pitkin's office pyrometer.

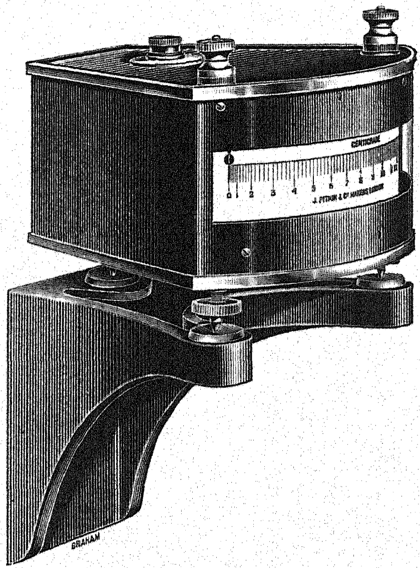


FIG. 192.—Pitkin's works pyrometer.

The nature of the records taken by the recording instrument is illustrated by figs. 193A, 193B.

Le Chatelier Pyrometer (Heræeus).—From a pamphlet kindly supplied by Mr. Charles Engelhard, of New York, the following explanatory excerpts have mostly been derived:—

"The scarcity of reliable instruments for measuring high temperatures, and the demand in numerous industries for such devices, prompted the Royal

REPRODUCTION OF RECORDS (Scale $\frac{1}{3}$) TAKEN AT A WELL-KNOWN IRONWORKS.

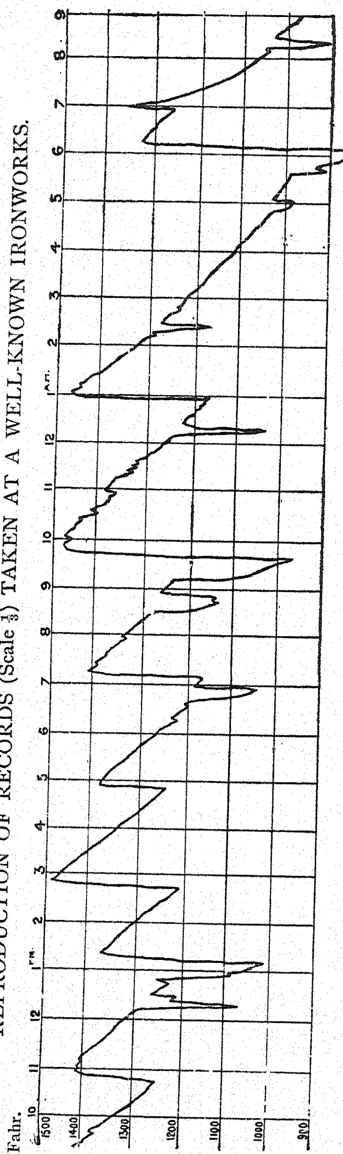


FIG. 193A.—Hot-blast record, showing drop in temperature due to neglect of workmen.

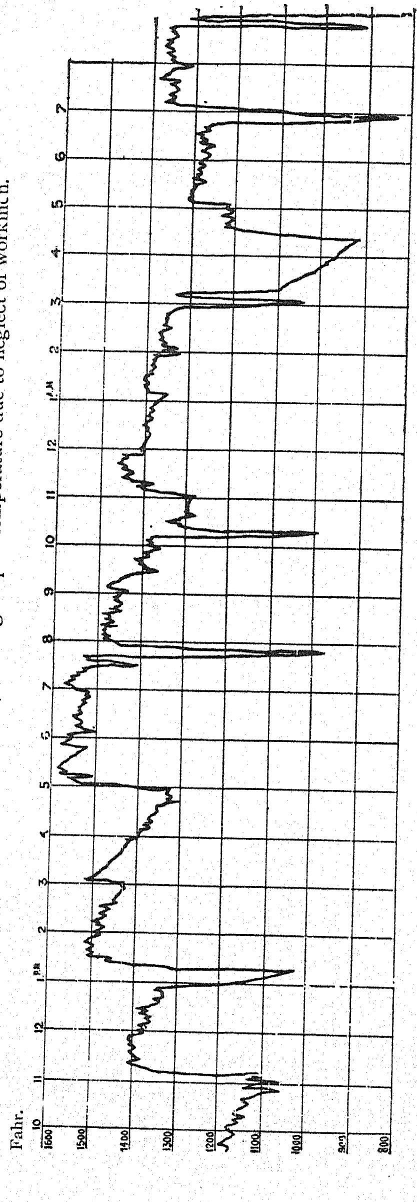


FIG. 193B.—Hot-blast record, showing curious variation of temperature due to hanging and slipping of charge.

(Reprinted by permission of J. Pilkin & Co., 56 Red Lion Street, Clerkenwell, London.)

Physical Technical Institute at Charlottenburg to intrust to Mr. W. C. Heræeus the manufacture of an apparatus according to the principle of Professor Le Chatelier, of Paris. The aim was to produce an instrument which would meet all modern requirements. . . . . The principle involved in the construction of this instrument is the conversion of heat into an electric current, and determining the fact that the temperature can be read off at almost any distance from the source of heat. The following description of the construction of the apparatus and the methods of its operation will demonstrate the wide range of its usefulness.

"Two wires, one of absolutely pure platinum and the other consisting of the same metal, alloyed with 10 per cent. of rhodium, are fused together at one of their ends in the shape of a small ball, and thus form a couple. This junction of two wires generates a slight electric current when heated, and as ascertained by the Royal Physical Institute, by comparison with the celebrated air thermometer in their possession, such currents are proportional to the heat applied. Each element is accompanied by a table of results determined in the same manner. To prevent injury to the wires from abrasion, injurious gases, and alloying with other metals, etc., they are usually enclosed in porcelain tubes; a small tube, open at both ends, covering the whole. The Royal Porcelain Factory at Berlin prepares such tubes from an extremely refractory porcelain base, which resists temperatures as high as 2920° Fahrenheit (1600° Celsius). The galvanometer used in connection with the pyrometer is of the d'Arsonval type, and especially adapted to the measuring of thermo-currents. The current is transmitted to an armature, wound in quadrangular shape, through a fine wire of hard metal, which does not oxidize; a small spring of the same material acts as negative. A strong permanent magnet with iron-pole shoes constitutes a magnetic field, an iron cylinder in the center concentrates the magnetic lines of force.

"The pointer moves over two scales, one of which denotes the electromotive force of the current in microvolts . . . . while the second scale gives direct readings of the degrees of temperature. . . . . Method of the application of the apparatus . . . . the end of the tube containing the two wires is exposed to the temperature to be measured, and the free ends of the wires are connected to the binding posts on the galvanometer; or, if desired, the galvanometer may be placed at any distance from the element, and insulated copper wires may be used to connect both. . . . . As soon as the temperature of the thermo-element has risen to that of its surroundings, the deflection of the pointer along the scales will cease. . . . .—W. C. HERÆEUS, Hanau."

It will interest ceramists to know that among the very large number of firms using the above-named instrument in its several modifications are Messrs. Villeroy & Boch, of Merzig-on-the-Saar, and Perth Amboy Terra-cotta Co., of Perth Amboy, N.J.

The London agents are David Thom Domeier & Co., who say that th instrument has met with great success in this country.

An abridged list of melting-points of some of the most useful metals, etc. selected from the pamphlet issued by Mr. Charles Engelhard, of 41 Cortland Street, New York, U.S.A., may be serviceable for comparisons.

Substance or Kiln.	Degs. C.	Degs. F.	Authority.
Gold, pure,	...	1913	Prof. Roberts-Austen.
,, standard alloy, Royal Mint,	1147	2097	,,
Silver, pure,	...	1773	,,
,, standard alloy, Royal Mint,	980	1796	,,
Platinum, fusible only before the oxy-hydrogen blow-pipe,	...	3227	,,
Copper,	...	1929	,,
Aluminium,	...	1157	,,
Zinc,	...	779	,,
Lead,	...	618	,,
Tin,	...	442	,,
Solder, fine—2 tin, 1 lead,	171	340	D. K. Clark.
,, common—1 tin, 1 lead,	188	370	Kent.
,, cheap—1 tin, 2 lead,	227	441	,,
Steel, 0·3 per cent. carbon, pouring into ladle,	1645	2993	,,
,, ,, ,, large mould,	1580	2876	Prof. Roberts-Austen.
,, commencement of casting,	1580	2876	,,
Iron, white cast-iron,	1135	2075	Prof. Le Chatelier.
,, grey ,,	1220	2228	,,
Red-brick kiln (Hofman's), burning temperature,	1100	2012	,,
Hard-porcelain furnace, heat at end of baking,	1370	2498	,,

The "Queen" Electrical Pyrometer.—The *British Clayworker* of September 1902 contains an instructive reference to this instrument. Therein it is explained as follows:—"The 'Queen' electrical pyrometer, manufactured by Messrs. Queen & Co., ... Philadelphia, ... is a modification of the self-recording electrical pyrometer of Professor Roberts-Austen. .... The pyrometer consists of a direct-reading galvanometer, a platinum couple, and a porcelain support. The galvanometer is mounted in a mahogany case 6 inches square, with a detachable lid. There are two spirit-level adjustments and two levelling-screws. The thermo-electric couple is 3 feet long. The pyrometer is portable, and is said to be accurate and durable, capable of measuring all kinds of temperatures .... between 500° and 3000° F., equal to 260° and 1649° C. respectively. The instrument is, moreover, said to be sensitive to 10° F., equal to 5·5° C., suitable in every way for work in connection with furnaces, ovens, kilns, stacks, etc. The price complete is $140, or £28, 15s. ..... In the 'Queen' electrical pyrometer the reading is taken direct. .... It should also be observed that in the latter instrument the length of the porcelain tubing, from the handle to the extreme ends of the wires forming the thermal junction, is altogether too short for kiln work; no provision is made for the thickness

of the kiln walls. For anything like accurate and effective work, the thermo-couple would require platinum-wire leads from 10 to 12 feet in length. . . . . The fundamental principles of good burning are plain; they are by no means difficult to understand, or to practically apply; the only difficulty is in getting them carried out. . . . . The kiln should be lightly, frequently, and regularly fired; the slowly rising temperature extending without break to the end.

"The 'Queen' pyrometer, with judicious handling and careful adjustment, should prove of . . . . value in determining . . . . faulty and irregular burning. However, while the operator . . . . is at the kiln adjusting and fixing the instrument, and waiting for an accurate reading, he can see practically to the stoking and burning operations himself. . . . . Now the Roberts-Austen self-recording pyrometer, having once been properly fixed and correctly adjusted, requires no attention at anybody's hands. The

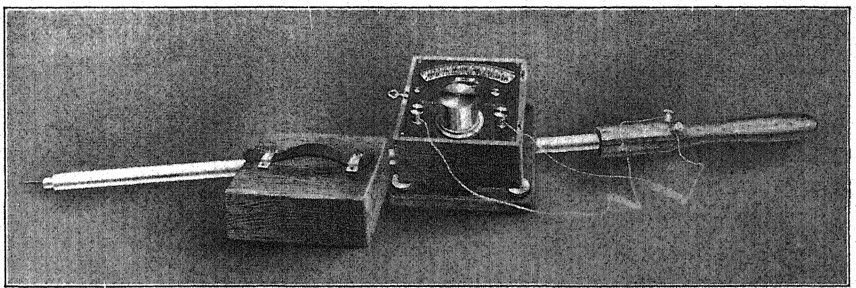


FIG. 194.—"Queen" electrical pyrometer.

burner may immediately take at any period of the burning a direct reading; and, what is more, a permanent chart is ever in course of construction, working independently of the burner, or of any supervision whatever, faithfully recording the work, good, bad, or indifferent, in connection with the burning operation of the kiln." (*British Clayworker*, September 1902, p. 203.)

Messrs. Queen & Co., writing on 30th April 1903, say:—"We are continually improving this instrument, and there are quite a number of alterations on the instrument that we are now making as compared with the illustration that we sent you last September. We send you a photograph of one of our latest pyrometers, which photograph shows the instrument equipped with a small switch on its face, so that it can be connected to a number of kilns at the same time, and reading one after the other by merely turning the switch, so that the couples in the different kilns will be thrown in circuit. There is also a switch on the face of the instrument, so as to throw all of the thermo-couples entirely out of the circuit, so that the hand will come back to zero

without disconnecting wires. The instruments have about four or five hundred ohms resistance, which makes them dead-beat, and also reduces the error due to the change in temperature or length of connecting wires to a minimum. We are in a position to furnish thermo-couples of uniform electromotive force, so that they can be used in connection with any pyrometer."

Cambridge Electrical Pyrometer.—The Cambridge Scientific Instrument Co., Ltd., of Carlyle Road, Cambridge, England, also supply electrical thermometers. In the paper on *The Measurement of Temperature*, to which reference has already been made, Mr. R. S. Whipple explains the principle of the two most important classes of electrical thermometers as follows:—

"*Electric Resistance Thermometers.*—In these thermometers the increase in resistance of a platinum wire with temperature is observed. The electric resistance thermometer was first proposed by Sir William Siemens in the Bakerian Lecture of 1871, and it immediately came into general use for metallurgical work. Unfortunately it was found that the pyrometer did not satisfy the fundamental criterion of always giving the same indication at the same temperature, and it was rather severely condemned by a committee of the British Association in 1874. It was found that these changes in resistance were due to a chemical alteration in the platinum. This change is very rapid if the platinum is quite unprotected, less rapid if the platinum is protected by a steel tube, and disappears if protected by a porcelain tube. All the volatile metals attack platinum readily, and the silica and the silicates must be avoided. In 1886 Professor Callendar showed that if the platinum is supported on a mica frame, in section that of a cross, with equal arms, there is perfect insulation without any cause of alteration. . . . . I would refer anyone interested to a paper published by him in the *Philosophical Magazine*, February 1899, entitled 'Notes on Platinum Thermometry,' which gives an excellent summary of his work. The results of his researches—and they have since been confirmed by many workers—is to show that the platinum resistance thermometer, if protected from strain and contamination, is practically free from changes over a range of 0–1200° C., and that it always gives the same indication at the same temperature.

"*Thermo-electric Thermometers.*—In these thermometers the electromotive force developed by the difference in temperature of two similar thermo-electric junctions opposed to one another is measured. Becquerel was, as far as is known, the first to use this method of measuring high temperatures (1830). He used a platinum-palladium couple. . . . . M. le Chatelier and Sir Roberts-Austen . . . . taught us what metals to use for our couples, what formulæ we should employ, and what apparatus we should use. Chatelier showed that very few combinations of wires make satisfactory couples.

Iron, nickel, palladium, and their alloys are absolutely unsuited for the measurement of high temperatures, since, when heated, these wires give rise to parasitical currents. . . . . He found, however, that platinum and its alloys, with iridium and rhodium, are fortunately free from these faults. . . . .

"Two methods are generally employed to measure the electromotive force of a couple: the potentiometric . . . . and the galvanometric. The first method is rather cumbrous for general workshop use, but it is undoubtedly the more accurate. . . . . The galvanometric method is simplicity itself, the cold ends of the thermo-couple wires being connected directly to the galvanometer terminals.

"If the resistance of the circuit is constant, the deflections will be proportional to the electromotive force. . . . . The advantages of the galvanometric method are its portability and simplicity; its disadvantages are closeness of scale and the fact that an error is introduced by the variation in resistance of the couple. The potentiometric method has the advantage of an open scale, and no error is introduced by the resistance of the couple. The only serious disadvantage is the fact that the apparatus must be worked in a laboratory and requires a trained observer." (*The Measurement of Temperature*, by R. S. Whipple.)

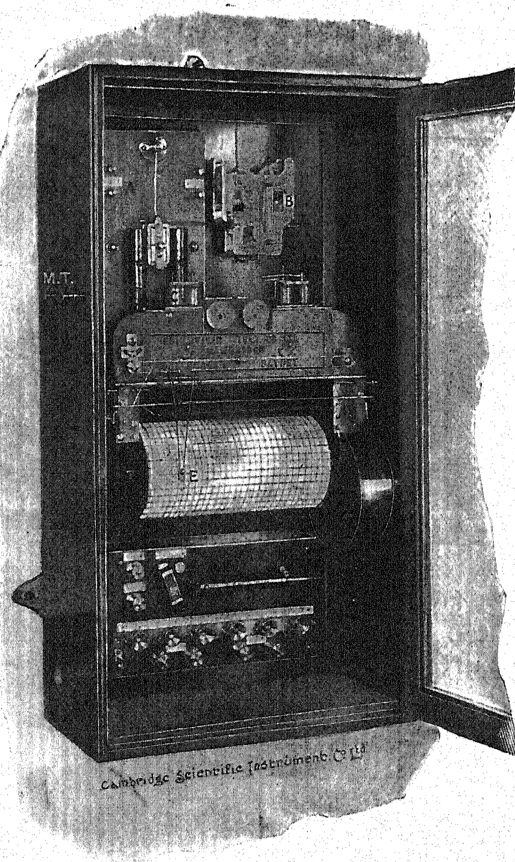


FIG. 195.—Callendar's patent recording resistance thermometer.

By the courtesy of the Cambridge Scientific Instrument Co. we are able to illustrate the principal forms of instrument referred to above:—

Fig. 195. The Callendar patent recording resistance thermometer, by which a continuous record of the temperature is obtained, and may at any time be

read off without disturbing the record, so that a glance will show whether the required temperature is being maintained or not.

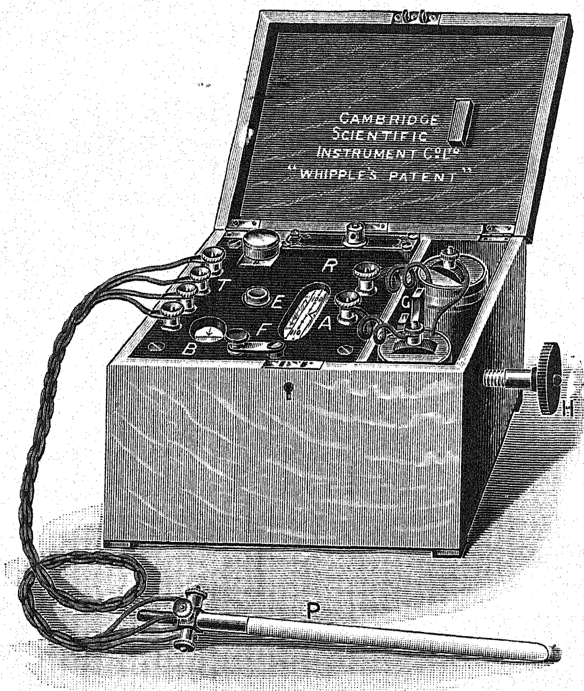


FIG. 196.—Callendar and Griffiths' patent resistance thermometer connected to a Whipple patent temperature indicator.

Fig. 196. A direct-reading Whipple temperature indicator and resistance thermometer, in which by depressing the contact-key F, and by turning the milled head H, the required temperature in degrees Centigrade or Fahrenheit can at once be read off on the scale at A. It is not essential that the indicator be near the thermometer, but may be placed at a considerable distance without affecting the accuracy of the readings. Thus a series of thermometers distributed over a considerable area can be read from one central station by means of an indicator and switchboard.

Fig. 197 is an illustration of the second type of pyrometer, viz., the thermo-electric, a type largely employed on the Continent for observing temperatures in smelting-works, foundries, etc. It will measure any temperature up to 1600° C., and is claimed to be useful for measuring very rapid changes of temperature, such as those taking place in a steam or gas engine cylinder.

"The couple consists of a platinum, platinum-iridium junction enclosed in a porcelain tube. The temperature obtained is measured on a special form of voltmeter (see fig. 197). Each division

FIG. 197.—Thermo-electric thermometer and indicator.

on the dial is equal to 10° C. Owing to the high internal resistance of the

voltmeter, the instrument may be set up at a considerable distance from the furnace without the necessity of making allowance for the resistance of the conducting wires or the temperature of the voltmeter. Thermo-electric thermometers, although not so accurate as resistance ones, are useful for employment in places where there is a risk of the destruction of the thermometer, their cost being less than that of the resistance ones. On the other hand, they have the great disadvantage that they require more frequent standardizing than, and are not so reliable as, resistance thermometers." (*The Measurement of Temperature by Electrical Means*, p. 13, Camb. Sc. Inst. Co.)

In commenting upon these instruments, a *British Clayworker* correspondent observes that "Within the limit of temperature above stated, the Callendar recording resistance thermometer is the best and most accurate of any the author has seen; but for fireclay and porcelain works, where higher temperatures are employed, the long exposure to great heat seems in some unexplained way to affect the resistance of the wire, and in this case one of the second-class or thermo-electric pyrometers should be employed." (*British Clayworker*, October 1903, p. 236.)

The same writer, in further comments upon pyrometry, makes the significant observation:—"It has been recently shown that at sufficiently high temperatures, such as are reached in porcelain glost kilns, fireclay itself becomes a conductor of electricity, and its resistance may therefore be made a measure of its temperature; but as this method cannot be used until near the finishing heat of the kiln, it has not received much attention, especially since the Callendar and Le Chatelier pyrometers cover the whole range of temperature." (*British Clayworker*, October 1903, p. 236.)

Automatic Wireless Electrical Pyrometry.—An inquiry addressed to our distinguished Staffordshire knight-professor, Sir Oliver Joseph Lodge, D.Sc., F.R.S., etc., as to the possibility of ascertaining the temperature existing in the interior of potters' kilns when under fire, by means of wireless electric currents traversing the kiln between electrodes fixed on either side, outside the kiln, elicited the following courteous explanatory reply, which may at least point the way for future inquirers in this field of research:—

"I think it is quite possible that something like a thermometric arrangement across the hot space inside a potter's kiln could be arranged without any interior conductors. I assume that carbons might be passed through the walls into the interior. The plan would be to measure the conductivity of the air inside; it is bound to depend on temperature, but it would not discriminate local from average temperature. I do not say that it would be automatic, and I think it might be troublesome. Moreover, a great deal of work on the subject would be necessary in order to make it possible. Some young student might take the matter up, but I have not anyone immediately in my mind.—Yours faithfully," (Signed) "OLIVER J. LODGE."

Immersion Thermometer.—When it is desired to make a more direct test of the calorific energy of the furnaces or kilns, either as an alternative in the absence of instruments such as those already described, or as a "control experiment," recourse may be had to the immersion thermometer referred to in Box's *Practical Treatise on Heat.* And, using the words of Mr. Phillip Kirkup (by consent), "The method consists in heating a mass of wrought-iron to the unknown temperature, immersing it in a known weight of water, and observing the increase of temperature produced. Thus:—Let 5 lbs. of wrought-iron, which has been heated to the unknown temperature (in this case of the heat of the kiln), be plunged into 10 lbs. of water at 60° Fahr., heating it thereby to 180° Fahr. Then $(180° - 60°) \times 10$ lbs. shows that 1200 units of heat have been given out by the 5 lbs. of iron, or $(1200 \div 5)$ 240 units per lb. The specific heat of wrought-iron being equal to one-ninth that of water, it must have cooled (240×9) 2160° Fahr., and the unknown temperature must therefore have been $(2160° + 180°)$ 2340° Fahr. We therefore have the following formula:—

$$T' = \left(\frac{(T - t) \times W \times 9}{w}\right) \times T,$$

in which t is the temperature of the water before immersion; T the temperature of the water after immersion; T′ the unknown temperature required; W the weight of the water in lbs.; and w the weight of the wrought-iron in lbs. He [Mr. Kirkup] had frequently used this method, and though not absolutely reliable, it gave a good estimate of the heat of the gases in kilns and coke-oven flues. The sources of inaccuracy in this method are chiefly the variable specific heat of wrought-iron and water; but, notwithstanding, it is perhaps the best practical method we have of ascertaining temperatures beyond the range of the mercurial thermometer." (*British Clayworker*, August 1898, p. 145.)

Transactions, North Staffordshire Ceramic Society.—Among the interesting abstracts from foreign journals, vol. i. p. 38 of the *Trans. N.S. Cer. Soc.* contains a short account by Cramer of the latest pyrometers introduced for ceramic purposes (from *Thonindustrie Zeitung*, No. 28, 1902).

(1) Hempel's Pyrometer.—It is sought to measure the length of the spectrum obtained by receiving the light from an oven through a refracting system, and this length is stated to be a measure of the temperature of the source of light. The difficulty in the use of the instrument lies in the impossibility of saying definitely where the spectrum commences and ends.

(2) Wanner's pyrometer depends on polarisation phenomena, and is in some respects similar to Mesuré and Nouel's instrument, differing from it by the readings being made in simple red light. The Nicol's prisms in the instrument are so arranged by the observer that the illumination of that part of the field receiving light from the oven and that part receiving light from a

standard lamp are the same in intensity. The temperature can be read off from a scale engraved on the instrument or from a table.

(3) Böttcher compares the intensity of the light radiated from the oven with that of a standard lamp by means of a "grease-spot" photometer.

(4) Holborn and Kurlbaum compare the radiation from the oven with an incandescent electric light which is seen projected in the field of observation. If the lamp is brighter than the oven, it is readily seen as against a dark background; if not so bright, it appears dark by comparison; when equal in illumination, it is invisible. The strength of electric current required to give this condition of equal brightness is determined by an ammeter. This is taken as a measure of the temperature. (*Trans. N.S. Cer. Soc.*, vol. i. p. 38.)

Other Considerations.—Temperature alone, however, does not cover all the mystery of potters' kilns. The powerful collateral influence of kiln-atmosphere is forcibly demonstrated both in the burning of Staffordshire blue bricks and of ruby-lustre ware. Heat brings into action strong chemical affinities that otherwise may be dormant. Under its influence, silica, for instance, becomes one of the dominant acid oxides, displacing most other acid oxides except boric. Then while all these new series of affinities are rampant, the presence or absence of excess of oxygen or of carbon is of great moment. Who will forecast, for example, the full effect of these widely differing conditions developed to their logical extreme in a tile biscuit oven?

Josiah Wedgwood confessed that some of his greatest difficulties and perplexities had arisen from not being able to ascertain the heat to which the experiment pieces had been exposed. And although possibly he hardly grasped the full importance of kiln-atmosphere, he nevertheless shrewdly confessed that "the brightness and luminousness of fire increases . . . . through numerous gradations which can neither be expressed in words nor discriminated by the eye."

Those who wish to probe more deeply into these matters will find useful information in Bulletin No. 54 issued by the U.S. Government, viz., *Thermo-electric Measurements of High Temperatures*, by C. Barns, and *Trans. of N.S. Cer. Soc.*, vol. i. pp. 42–44.

CHAPTER VI.

BLUE AND RED FLOOR-QUARRIES.

CONTENTS.—Use of floor-quarries—Clays—Analyses—Preparation of clays—Moulding—Drying—Kilns—Setting in—Burning red quarries—Burning blue quarries—Chemistry of bluing.

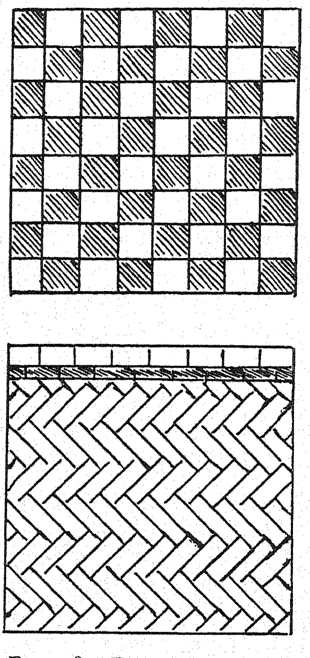


FIG. 198.—Two modes of laying floor-quarries.

COMMON blue and red quarried flooring is perhaps the most elementary expression of decorative ceramic art, constituting an intermediate zone, wherein the useful and ornamental blend together, rather than any serious decorative attempt. This arises not so much from absence of artistic possibilities in these simple products—for their colour is often of very lively tone—as from the remarkable development of the art of making polychrome tessellated floors, which has accustomed us to a richness of effect disproportionately belittling the plainer article.

The same thing is happening on every side—our homes, our clothing, our food, our pleasures, overflow with luxury and variety of colour and form, and all that art and science can devise. Even in artisans' dwellings plainer flooring materials are becoming relegated to humbler apartments.

It is well that for these commoner purposes an article can be manufactured at comparatively small cost by simple means, and still fulfil the hygienic needs of the case as satisfactorily as more expensive products; at the same time not necessarily offending good taste, nor presenting a surface altogether devoid of interest.

For plastic-made red and blue quarries are almost always sufficiently impervious to make a good floor, and individual shape and mode of laying may accomplish much toward enhancing appearances; even the joints, when judiciously arranged, contributing powerfully to the general effect (see fig. 198).

This class of flooring is not usually made in decorative-tile works, but its very general use for kitchens, larders, and secondary passages makes reference to it here desirable.

Accordingly the permission of a friend—himself an experienced manufacturer of such goods—was solicited, and granted, to describe the manufacturing processes as conducted on his works.

The Clays.—The geological strata made use of for this purpose in North Staffordshire are principally selected from the red, purple, and mottled marls of the "Etruria marl series" of the upper coal-measures. According to the Memoir of the Geological Survey of the country around Stoke-upon-Trent, the division known as the "Keele" series has not been used for this purpose, although red clays of similar appearance, and belonging to the same geological horizon, are reported to be used for making terracotta near Wrexham, North Wales.

The clay quarries are usually open workings, mostly situated on hillsides, where the outcrop or cliff exposes a clay-face of considerable depth and variety. The clay-seams are often interspersed with beds of gritstone and thin layers of shale, and are sometimes impregnated with concretionary or fragmentary foreign substances detrimental to the products. Considerable differences in quality also exist in adjoining seams; hence long practical experience of a particular clay-pit and constant watchfulness over the getting and the mixing are desirable.

Respecting chemical analyses, Muspratt gives the following series of analyses of clays at Basford, near Etruria (Staffordshire), and comments upon the character and product of each:—

	1.	2.	3.	4.	5.	6.	7.	8.
Silica,	42·84	54·38	59·44	60·02	64·32	65·78	69·87	70·17
Alumina,	17·61	26·55	55·93	24·26	20·33	15·16	16·79	16·25
Sesquiox. iron,	6·97	...	10·74	9·14	10·86	8·47	8·88	8·41
Protox. iron,	...	8·38	...	...	...	...	...	...
Lime,	15·36	...	...	1·60	trace	1·67	trace	1·29
Carbonic acid,	11·61	3·14	...	...	...	...	...	...
Ox. manganese	2·20	...	trace	trace	...	...	...	...
Alkalies,	...	...	...	1·40	...	...	...	..
Water,	3·94	7·28	3·11	3·89	6·60	5·37	4 26	5·86

No. 1. Rotten red marl, will not stand heat, but fuses.
2. Seggar marl, burns light buff—a firebrick.
3. Mixture of clays 5, 6, 7, 8, burns a good blue.
4. Clay from Stoke-on-Trent, burns red.
5. Dun-coloured marl, burns good blue.
6. Top yellow marl, burns reddish blue.
7. Red marl, burns blue.
8. Mingled marl, burns blue of a reddish tint.

Numerous other analyses of red clays will be found in Chapter IV.

Preparation of the Clay.—The various seams of marl are all got separately, and the harder veins allowed to weather, so as to break down the lumps and soften the clay through. Then the various sorts are mixed as dictated by experience, according to the particular articles it is intended to manufacture; which in the case of red quarries may provide a slightly finer and less fire-resisting kind than the compound for blue goods; the mixing of the clays being effected when wheeling into the wagon which conveys the clay to the grinding-mill. The mill may consist of either three pairs of heavy iron rollers, or a grinding-pan and one or two pair of rollers. It is of fundamental importance that the mills are constantly maintained in good repair, so that grinding may be efficiently performed, for neglect in the grinding tells disastrously upon the products.

After the first grinding, the clay is put into heaps, watered, and left to soak and to become somewhat more even consistency. Afterwards it is turned over again with the spade and more water added if needed. After standing a day or two, the mixed ground clay is passed through another pair of rollers and a pug-mill, and then taken to the moulder ready for use. Here, again, care must be exercised that the clay is not excessively moist; if it is, cracking is more likely to arise during the drying.

For certain special superior qualities of 4-inch by 4-inch quarries, and smaller sizes, the clay is, at some works, refined by mixing with water and blunging until it assumes the condition of slip. This slip is then passed through sieves, and afterwards boiled down to a plastic state on a heated kiln floor, or upon steam-heated shallow tanks.

Moulding and Pressing.—The usual process is to take clay prepared by the above-described methods and make "clots," *i.e.*, rough tile-shapes, approximately of the desired form, by beating out bats of clay and forcing them into strong wooden, iron, or brass moulds of the requisite size.

In the case of quarries intended to be burned blue, a dry fine dust, made from coal or coal and ashes, or even finely riddled ironstone "mine" ashes, is used to dust inside the moulds before inserting the clay, so as to prevent the clay from sticking in the mould.

In the case of quarries intended to be burned red, a dried fine dust of the red clay itself is used to dust the moulds with. The clots or rough tiles are soon turned out of the moulds and put upon a warm floor to stiffen, and, when they arrive at the required condition of hardness, are gathered up and stacked together in heaps to equalize in stiffness and to toughen. Then they are pressed between oiled dies in a metal mould by means of a powerful screw-press. The ordinary sizes of quarries made are 9 inches by 9 inches by $1\frac{1}{4}$ inch, 6 inches by 6 inches by 1 inch, and 4 inches by 4 inches by $\frac{7}{8}$-inch. For these the metal dies should be respectively 10 inches by 10 inches, $6\frac{3}{4}$ inches by $6\frac{3}{4}$ inches and $4\frac{1}{2}$ inches by $4\frac{1}{2}$ inches.

Drying.—The drying of plastic-made quarries needs much careful attention and experience. When made of some kinds of clay the goods require to be well dried before setting in the kilns; whereas when made of other clays, particularly those of fine grain, there is a great tendency to "cut" or crack across the corners during drying, and it is found to pay better to set them in the kiln as soon as they are dry enough to stand firmly and bear the weight of articles placed above them in the kiln.

This will, of course, appear very contrary to orthodox teaching, which usually insists most strongly on drying before burning. Nevertheless experience of a practical nature in actual working brooks no discussion, and if it is found necessary to take a certain course so as to bring out of oven the greatest possible quantity of best saleable goods, theories will have to accommodate themselves to facts; the manufacturer must obey the teachings of actual experience.

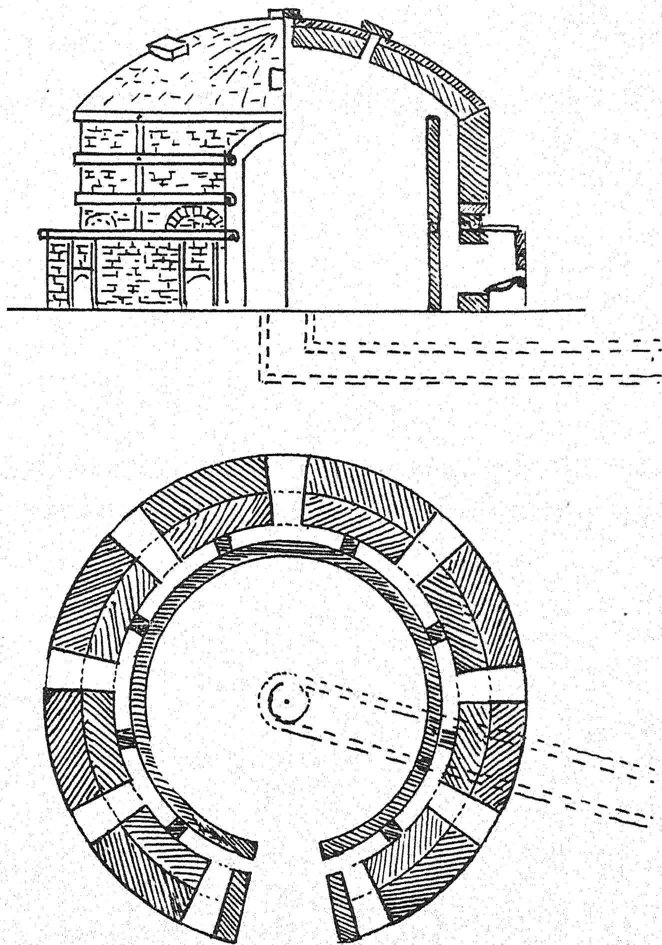


FIG. 199.—Beehive kiln for quarries.

Kilns.—The sort of kiln in which blue and red floor-quarries are most usually burned in North Staffordshire is the down-draught beehive brick-kiln, 15 to 17 feet interior diameter and 7 or 8 feet interior height, with nine or ten furnaces or fire-mouths built around outside and penetrating the kiln wall.

An interior casing or continuous firebrick screen-wall 9 inches thick is

carried up solid all round the interior, except the entrance, at a distance of 9 inches from the main kiln wall and up to within 9 inches of the crown arch. Connecting supports forming partitions are built between the screen-wall and the main kiln wall at intervals, *i.e.*, between each fire-mouth, and these support the screen-wall, and at the same time guide the heat and flame upward when first they enter the kiln.

The bottom of the kiln is generally solid earth, with a central well-hole to the chimney flue, and the fire is guided or regulated by a chequer of five or six or sometimes eight rows of bricks in the bottom, set there for burning, under the blue or red quarries.

The fire-holes are built up at the front and fired from the top. Many fire on dead-bottom, but some use loose bars for smoking, and pull them out for the last twenty-four or thirty hours.

Some instructive details of brick and tile kiln construction and management will be found in *Brick*, May 1903, pp. 208–212 (Windsor & Kenfield, Chicago).

Setting in the Kilns.—No saggars are used for these goods. They are set in the kiln unprotected otherwise than by the particular manner of placing in the kiln, and by the screen or flash wall that breaks the first rush of the flames.

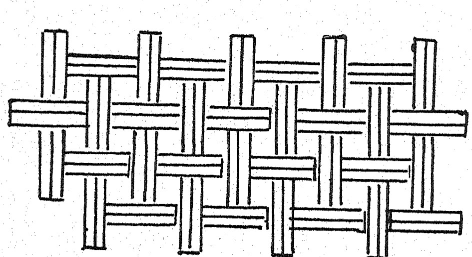


FIG. 200.—Basket-work mode of setting quarries in kiln.

In the case of red quarries, the bottom part of the kiln, or "chequer" part as it is called, that is to say, up to a height of about 3 feet, level with the top of the fire-mouths, is filled up with unburnt bricks five or six rows. Above and upon these bricks the kiln is filled with quarries. These may be placed in couples face to face, in the manner indicated by fig. 200, to enable the heat to circulate freely without exposing the tile-faces to the flame. Or a floor of burnt quarries may be formed on the top of the chequer, and the quarries set face to face and back to back, solid right along, leaving airways for the draught to traverse between the rows.

For blue quarries, the quarries are all more or less separated from each other in the kiln, being placed so as to allow free play of the heat and the subsequently induced reducing atmosphere over the whole surface of each article as far as can be.

Burning.—Burning or "firing" of clay-wares effects several very different things successively in the one operation: firstly, so much of the moisture as has been associated with the clay to facilitate manufacture, and not subsequently dried off, must be dispersed, and this creates steam that is observed to

issue from kiln-top vents and chimneys during the first stage. When this is quite cleared off, the combustion of organic matter, if any be present, takes place, and then the combined water is driven off. Concurrently, or shortly afterwards, volatile gases escape, and if the heat be continued, colour is developed; this may be followed or accompanied by cementation or fusion, until a good ringing quarry results.

Clays, however, differ very much, and the above forecast of the phenomena may not invariably correctly indicate the sequence. G. F. Harris, in his *Science of Brickmaking*, writes:—"It is frequently laid down that such and such a temperature will form a red brick, and another and higher temperature a blue one. That is a most absurd notion. In a general sense the principle could be correctly applied to a limited district, and with one class of brick-earth, but it cannot be made to apply all round. There is nothing like experience in regard to a point like this. In a general way, of course, a pink, red, or blue tint may be produced from one brick-earth depending upon the temperature employed; but the bulk of brick-earths would melt and the whole kilnful be ruined in any attempt to attain such a temperature as is used in burning a sound 'Staffordshire blue.' Quite a large number of bricks made in the southern half of England may be described as having been dried in the kiln only—they cannot be said to be burnt, except that the heat employed was enough to turn them red, or to make them piebald: the particles are not agglutinated by fusion, and, indeed, there is often no trace of the constituents having been melted. On the other hand, we have red bricks in which the constituents are distinctly agglutinated by fusion, and the whole burnt thoroughly. The brick-earth of which these latter are made would barely turn tint—would certainly not become red—at so low a temperature as that employed in producing the red in the non-agglutinated bricks alluded to." (*Science of Brickmaking*, p. 99, H. G. Montgomery.)

In burning red floor-quarries in Staffordshire, after the kiln has been "set in" and the "clammings" built up in the doorway and well luted, it is customary to "smoke" the kiln, by first of all making and maintaining small slowly-burning fires for three or four days and nights, very gradually increasing the heat, and meanwhile providing for the due escape of steam through the top vents. Afterwards the vents are covered, and the fires are increased for three or four days and nights longer, the burning being completed within about a week from starting to "smoke" the kiln. In the whole period when burning red quarries, more air is usually admitted through the fires than is the case with blue goods; and the fireman is guided, when finishing, by small trials made of the same red clay-body which he withdraws from the kiln from time to time. When firing is finished, the fire-mouths are left open and undisturbed for two or three days, and then the goods are withdrawn from the kiln, rather more than fourteen days having been

occupied in "setting in," "smoking," "burning off," "cooling," and emptying. The foregoing more particularly applies to a red-quarry kiln and to one Staffordshire works; other works may proceed somewhat differently, occupying more time, possibly, if the kilns are of greater size, or the "setting in" and emptying not expeditiously attended to. For instance, some kilns are 21 feet diameter, and this, as compared with a kiln 15 feet diameter, makes an appreciable difference in duration of burning. After all, very much depends upon the ability and attentiveness of the fireman, and it does not even follow by consequence that the man who has had longest experience will always bring out the largest number of best goods: habit is sometimes so strongly ingrained as to prevent a man adapting his methods to the needs of the clay.

In burning blue floor-quarries in Staffordshire, the kilns are slowly smoked with "slack" fires for three or four days and nights; then greater heat and quicker fires are put on, using some larger coals along with the slack (fine small coal), for a period of three days and two nights, or until the required heat is obtained, as observed by small trials of the same kind of goods, withdrawn from trial-holes of the kiln from time to time. An intense heat is attained, and then during the last eight or ten hours of the firing the dampers are closed down.

Immediately upon completion of the burning, all fire-mouths are carefully closed, so as to exclude air for two days and two nights whilst the kiln cools, about fourteen days being occupied in the filling, firing, cooling, and emptying.

In this case, too, some differences of time and treatment necessarily arise at different works. In some works manganese dust is said to be blown into the kiln when finishing the burning; in others the fireman casts in a little salt when the dampers have been closed, with the object of assisting the bluing or reduction process. As a rule, however, with good clay and proper firing such extraneous and questionable helps are better avoided; at anyrate, that is the pronunciamento of the experienced practical friend to whom the author is so largely indebted in this matter for information.

The weight of goods burned in one kiln may be forty or fifty tons.

It will thus be seen that to properly effect the several objects of burning red and blue quarries, time of burning, temperature of burning, and atmosphere of burning must all be carefully controlled. Mr. William Burton, F.C.S., expressed this fact in a very interesting manner in his paper, "The Palette of the Potter," read before the Society of Arts on 25th February 1896. He said:—"One of the commonest results in a manufactory where coloured bodies are largely produced is the appearance of streaks or patches of darker colour on the ware after firing. Buff articles will come out streaked with red, red may be changed to chocolate or to a purplish black, and even the aggressive blue of Wedgwood's jasper may be found at times subdued to a deeper tone. . . . .

There are dozens of Greek vases in the British Museum . . . . where the figures that should have been red . . . . have been turned wholly or in part to a dark purplish colour, often with great resultant charm. All these variations, with others of a similar kind, are due to the variations, not so much of the actual temperature, as of the atmosphere produced by the firing, and which must circulate round and about the articles inside the oven. . . . . The most extreme instance of the kind under consideration is shown in the production of the Staffordshire blue bricks and roofing-tiles. In this case a clay that would in the ordinary course burn to a full red colour is fired in such a way that dense volumes of black smoke are turned into the oven during the last hour or two of firing, with the result that the red oxide of iron in the clay is deprived of part of its oxygen, and is converted into another oxide of iron, the magnetic oxide, which is of a purplish-black colour." (*Jour. Soc. Arts*, 28th February 1896, p. 323.)

CHAPTER VII.

PLAIN AND ENCAUSTIC FLOOR-TILES AND TESSERÆ.

CONTENTS.—Definitions—Desirable qualities—Durability—Colour—Exactness of size—Foothold—Discoloration—Frost resistance—Strength—Preparation of bodies—Dusts—Tile-pressing—Encaustics—Biscuit oven—Burning—Sorting—Recipes for bodies.

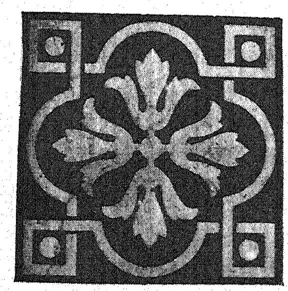


FIG. 201.—Encaustic tile, buff on chocolate.

PLAIN floor-tiles may be defined as unglazed tiles usually of geometrical shape, devoid of ornament, of one colour throughout the entire mass, and burned until sufficiently impervious to resist permanent discoloration in ordinary use.

Encaustic floor-tiles are generally understood to be figured, inlaid, or incrusted floor-tiles, usually not glazed, the upper surface level, but having patterns inlaid in the surface in the clay state, and burned in as part of the tile itself, the colour of the figure or pattern differing from the colour of the main body of the tile.

Desirable Qualities.—In the manufacture of these elements of tessellated floors certain desirable, if not essential, qualities must be provided, namely, uniform durability, evenness of colour, distinctness of colour, regularity of size, good foothold, level surface, tolerable fineness of grain, insusceptibility to permanent discoloration, facility in cleansing, frost resistance, strength, adhesion to cements.

Uniform Durability.—Those who remember the cobble-stone pavements of country towns will not need telling how desirable it is that ornamental flooring-tiles should not only wear well, but wear evenly and uniformly, otherwise the harder tiles eventually form raised patches annoying to walk upon. In small private dwellings this defect may be a long time in showing itself to any objectionable degree; but in much-used situations, such as the booking-halls of railway stations, hotel entrances, vestibules of public baths, municipal buildings, and the like, differences in durability soon become accentuated.

To avoid or lessen this defect the obvious manufacturing precautions are either to compound all bodies on a similar basis, and endeavour to burn all the product as evenly as practicable; or to meet the variations of temperature of the several parts of the biscuit ovens by variations in the nature of the bodies, to bring all out as evenly hard as colour and vitrescence permit; and rather than allow under-burned tiles to be used for flooring, either burn them again, or pass them on to the glazing department for other uses.

Experience indicates that usually red, chocolate, and black floor-tiles wear away more speedily than cane, drab, white, or blue tiles, and that common plastic-made red and blue floor-quarries wear longer than dust-made red or chocolate floor-tiles. For this reason the introduction of a certain proportion of vitreous red clay or ball-clay in red bodies is desirable.

To ascertain promptly the comparative wearing qualities of floor-tiles, a "foundry rattler" may be used, as in testing the relative susceptibility to abrasion of road-paving materials. (See p. 146, *Science of Brickmaking*, *British Clayworker* publication.)

Evenness of Colour.—To ensure this quality there must be very careful selection of the clays and water used, scrupulous accuracy in compounding and blending the body-clays, care in drying the product, care in burning, and efficient sorting in the warehouse. Some clays are more liable to become stained or "strike" during drying and burning than are other clays. When this occurs—whether from the presence of soluble colourants or from the evolution of gases—two courses are open, namely, either to discard the delinquent clay or water, or to adopt special treatment. For instance, buff tiles, which are often liable to this irregularity, may be placed for drying and burning with pairs of tile strips 6 inches by 1½ inch interposed between the pairs of 6-inch by 6-inch buff tiles.

Distinctness of Colour.—Brilliant gem-like tints are not to be expected among coloured earthenware bodies; nevertheless for decorative flooring something more than nondescript hues are needed. A moderate degree of liveliness of colour must be attained, and must conform to well-defined shades recognized in the trade. For example, red floor-tiles should incline toward crimson or maroon shades; bright blues must be attained by associating barytes or oxide of zinc with rather felspathic compositions, to secure good development; greens, too, are developed best in the presence of felspar or similar ingredients. Mr. W. Burton, F.C.S., expresses this very clearly thus:—"The finest artificial clay colours only develop any considerable brilliance of hue when they are added to clay-bodies which partially fuse or vitrify in the fire." (*Jour. Soc. Arts*, 28th February 1896, p. 322.) Buffs and reds may perhaps be exceptions, but for many colours vitrescence is undoubtedly favourable.

Regularity of Size.—It is astonishing how large small things may appear

when massed together—for example, the snowflake and the avalanche, the grain of quartz and the mountain, the private soldier and the regiment; so also, though in less degree, variations from standard sizes in floor-tiles, when accumulated by being laid consecutively, soon become so considerable as to seriously interfere with the design unless unsightly joints are to be tolerated. Hence constant attention must be paid to the dies and moulds, and body-clays must as far as practicable be made from large heaps of well-averaged and equalized clay; the clay-dusts must be evenly ground and regularly damped; and drying and burning effected with an ever-present consideration for keeping to correct size.

Good Foothold.—Although it may not be possible in a ceramic floor to impart that happy sensation of security experienced when walking upon sandstone flags, it is undoubtedly desirable to attain us much of it as conditions permit. Tinkling sound and excessive slipperiness are objectionable, if not a source of danger. A moderately high percentage of free silica in a tile-body will furnish a close approximation to sandstone; but other considerations, such as cohesiveness of the dust-clay, strength, and imperviousness, render it imperative to restrict the free silica within certain limits, and to reduce to a fine state of subdivision whatever silica is introduced in the body. In special instances ribbed-faced tiles are made with the object of securing good foothold or safe tread; but these are not often suitable for highly ornamental floors.

Level Surface.—Smoothness of the dies, accurate action of the plungers, aided by careful fettling, must be looked upon as indispensable in the production of good surfaces. Also the setter-tiles upon which unburnt tiles are laid must be as true and level as possible, and clays liable to blister or warp should be discarded. Freckling and veining are said to arise from the use of unmellowed dust-clay, and these irregularities may affect the surface.

Fineness of Grain.—Fine grain or texture yielding smooth fracture is attained by the use of fine sieves both for slips and for dust-clay. Perhaps 100^{h} mesh brass-wire slip sieves (or 14^{s} silk lawns) and 12^{s} mesh dry sieves are the extremes, because excessively fine dusts, particularly when dry, may cause what is known as "windblow" of the tiles, a very troublesome defect. Evenness of damping and mellowing of the dust are also required to induce fineness of texture.

Discoloration in Use.—Owing to differences in colour, and to the expedients necessary to develop good tints, it is scarcely practicable to impart equal vitrescence to every floor-tile. Probably the greater number of buff, red, drab, and chocolate coloured tiles are partially porous, and not of the same impervious nature that blue, green, and white tiles usually are. Hence arise differences in liability to discoloration; yet it is important to maintain a reasonable degree of facility in cleansing by ordinary domestic means, and therefore low absorption standards should be maintained.

Langenbeck very tritely writes:—" Sidewalk blocks and paving-bricks are now frequently required to show less than 1 per cent. absorption of water by weight. Floor-tile are not subjected to as severe conditions, but if they do take up more than from 3 to 4 per cent. by weight of water, they become difficult to keep clean from the grinding of dirt into their pores. The following data, averaged from a considerable number of tests made on commercial wares of all makers represented in our market, will show that while there is much that amply fills all requirements, the average by no means does.

WATER ABSORPTION OF FLOOR-TILE.

Colour of the Clay.	Percentages by Weight.	
	Extremes.	Average.
Salmon,	1·5 to 9·1	5·8
Buff,	1·9 to 7·2	4·6
Light gray,	1·9 to 8·5	5·8
Dark gray,	2·0 to 5·8	4·4
Chocolate,	0·0 to 7·4	4·8
Red,	1·5 to 8·4	6·0
Black,	4·4 to 10·3	7·5
Fawn,	...	8·3

"In making the test it is important not to immerse the entire piece in water, as this would seal the pores and make it very difficult to get rid of the air in the interior. One face of the specimen must be left dry, and the water allowed to rise by capillarity, the piece not being lowered under the surface of the water until all its air has been expelled. It is superficially wiped off before weighing." (*Chemistry of Pottery*, pp. 156 and 24.)

The requisite degree of vitrescence should therefore be attained by adding vitreous clay to red, chocolate, black, and drab floor-tile bodies, and this will at the same time increase the durability. Imperviousness is desirable also to lessen liability to alternating absorptions and evaporations of humidity with each atmospheric change, and to retard rising damp from the earth below. Yet, again, this vitrescence must be moderated to escape slipperiness.

Frost Resistance.—Porosity coupled with lamination arising from incipient "windblow" are probably the chief sources of weakness in this respect. Therefore homogeneity and imperviousness are the qualities to be imparted if we would render the tiles capable of resisting frost. Of course when a tile is badly "windblown," the fault manifests itself immediately upon removal from the press, and the tile may be promptly thrown aside, to be reground into dust-clay and remade into tile.

Probably, however, there are degrees of "windblowing" so infinitesimal

as to pass unobserved through the kilns and warehouse, and these, when subjected to damp and frost, may develop defects hitherto unnoticed. Or, indeed, it is possible that certain paths through which the pressure was imparted when the tile was being made, may in every tile exist until fusion or semifusion obliterates them, much in the same way that the spiral path of the thrower's manipulation of plastic clay on the potter's wheel is sometimes traceable in the product after burning.

Strength or Toughness.—For cutting purposes it may be convenient to have a tile that may easily be broken to fit into and fill up a space. But, as a rule, the power of bearing sudden impact without fracture is a desirable one in floor-tiles. Cracked tiles in a tessellated floor, or tiles with shattered edges, are very unsightly.

Apart from differences in the behaviour of individual clays, it is well known that refined clays and ceramic body compounds may be burned to three conditions widely differing in respect of tensility or cohesion, viz., a fragile condition, like meal-cake, when under-burnt; a tough condition, almost like cast-iron, when thoroughly and properly burnt; and a brittle condition, like glass, when over-burnt, with intermediate gradations.

This seems to indicate that careful burning is the chief contributor to good results, every other possible cause being minor or secondary.

With regard to tests, G. F. Harris states that Fickes, of Steubenville, as the result of many tests in connection with bricks, came to the conclusion that the strength varies in tolerably close inverse ratio with the quantity of water absorbed in twenty-four hours, the strongest bricks absorbing the least water. Poor building bricks, which, when tested, absorb one-seventh to one-fourth their weight of water in twenty-four hours, average little more than one-half the crushing strength of good bricks, which absorb only 6 to 12 per cent.

These observations appear to be confirmed by the fact that the crushing strength of Staffordshire blue bricks usually greatly exceeds that of ordinary bricks. (See *Science of Brickmaking*, pp. 133 and 141, H. G. Montgomery.)

Adhesion to Cement.—The next requisite for all good floor-tiles is to be placed in a suitable situation for a useful life. Fixing and laying, of course, are no part of the manufacture, but it behoves the tile manufacturer to see that his product is given a good start in life, so to speak; and in practice it has been found advantageous to undertake the laying, and see that it is done by careful, reliable men.

One way of forming a foundation is to thoroughly ram the whole area as evenly as possible, and then spread over it a layer of stones 3 inches deep, the stones to pass through a 2-inch ring; over these spread good concrete 2 or $2\frac{1}{2}$ inches thick, finishing it level and allowing it to harden. (See *Work*, 20th September 1890.) Upon this foundation, moistened, a bed of Portland cement mixed with sharp sand is spread and levelled by pushing a lath along

its surface, the lath being supported at either end on strips of wood fixed on the foundation at the correct height. Upon this cement bed the tiles, previously soaked in water, are laid according to pattern and plan, and beaten down by means of pieces of wood placed on the tiles and struck by a hammer. Subsequently the floor-joints are grouted, and the surface cleaned and spread with sawdust. The floor should not be walked upon for five or six days after laying.

The necessity for soaking tiles prior to laying, confirmed by a similar necessity for soaking building bricks in dry, hot weather, appears to indicate that a well-burnt tile is really better than an excessively porous one for good and permanent adhesion.

In hot weather, means should be taken to retard evaporation from the surface of a newly laid tessellated floor, so as to give time for the peculiar growing together of the tile and the cement.

Finally, with reference to foundations, one incident from history may serve as a useful reminder of the necessity for care. Marryat says:—"The new Royal Exchange was in the first instance paved with azulejos, but in consequence of the bed of composition on which they were laid proving defective, or from the heat of the sun's rays expanding the particles of air, the tiles 'blew up,' and the whole pavement was taken up and replaced by the original Turkey-stones, which were a present from a merchant in olden times, and fortunately had been preserved." (*History of Pottery and Porcelain*, p. 405, Murray.)

Preparation of Bodies.—The most important preliminary step in compounding floor-tile bodies is to secure suitable clays and marls. So great a difference is qossible in the quality of tiles produced from various clays, that this may exercise a preponderant influence for success or disaster.

After selection, weathering, turning over, and picking out undesirable fragments from the clays or marls, the "bodies" may be prepared by one or other of the following methods, or variations of them, separate sets of apparatus being used for dark and light bodies:—

(*a*) For cheap tiles, made either from one native clay or from a simple mixture of several clays, naturally soft, the body may be prepared by drying and pulverizing each component separately, and then measuring out the quantities of each according to formula. These are intimately mixed together and wet-ground under edge-runners on a solid-bottom pan, then pugged. The pugged composition is subsequently dried, damped, and disintegrated, passed through 8^s or 10^s mesh dry sieves, and placed aside in a bin to mellow.

(*b*) A second method is to weigh or measure the marls, clays, and other ingredients and stains, and place them together in a tank with double their volume of water, and allow the whole to soak for several hours. After

soaking, the mass must be "blunged," *i.e.*, intimately mixed together until it forms a cream-like slip. This slip is passed through slip-sieves of 80^s or 90^s mesh, and run upon a quarried drying-floor to a depth of 6 or 8 inches, and boiled by heat from flues underneath the floor or kiln until the clay is completely dry. The dried clay is afterwards damped, disintegrated, and sieved through 10^s mesh dry sieves, and placed in a bin to mellow.

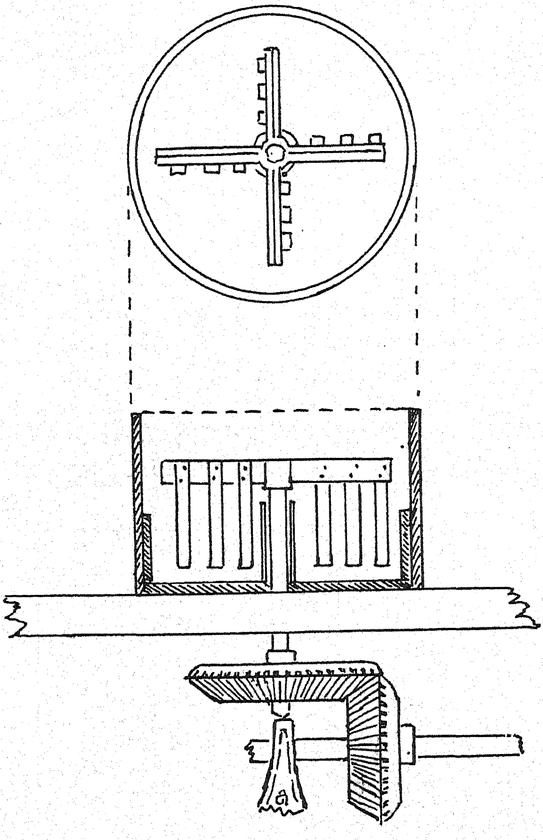


FIG. 202.—Arm-blunger for rough marls.

(*c*) A third method. The weighed proportions of marls, clays, etc., are thrown into a steam-power blunger, and sufficient water admitted to form a slip. After blunging for some hours, the composite slip is run into a shallow tank, from which it slowly passes through a tier of slip-sieves, say 60^s and 90^s mesh, and then runs on a quarried floor to be boiled dry. Afterwards the clay is damped, disintegrated, sieved through 10^s mesh dry sieves, and placed in a bin to mellow or condition itself; or the dried clay may be ground dry and then damped on plaster beds.

(*d*) A modification of (*c*), thus:—After sieving the compounded slip, run it upon a drying-floor either of metal or bricks, upon which rests a range of steam-pipes. Exhaust or live steam is passed through the pipes to boil and dry the slip; when this is completed the pipes are drawn up by means of a chain and windlass, and the dried clay removed for grinding and damping.

(*e*) Another variation of (*c*) is as follows:—After the slip has been sieved, allow it to fall into an underground tank, from which it is pumped into hydraulic filter-presses, and is thus brought into the plastic-clay state. It is afterwards dried by any economical means either on stillages in a heated room, or on a heated quarried floor.

(*f*) In the case of coloured vitreous tile-bodies, of which usually only

comparatively small quantities are needed of one colour, a given quantity or measure of the slip of white vitreous body may be intimately mixed with the necessary colourant, in a finely levigated slip condition; the mixture sieved, and then dried in large bowls, or on portions of the drying-kiln, or in any convenient way. When dry, it is ground in a small flat-stone mill and damped.

(*g*) The use of tube-mills, as commonly employed in Portland cement

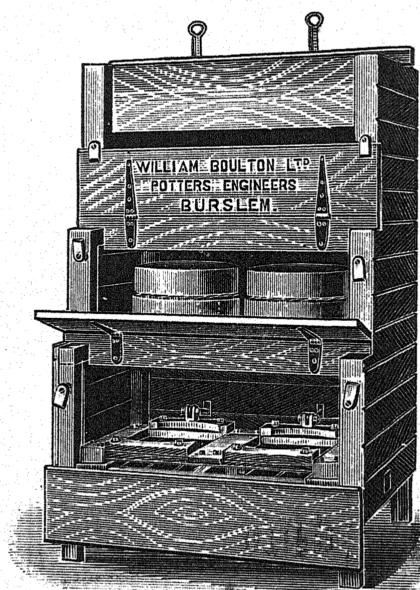


FIG. 202A.—Tier of slip sieves.

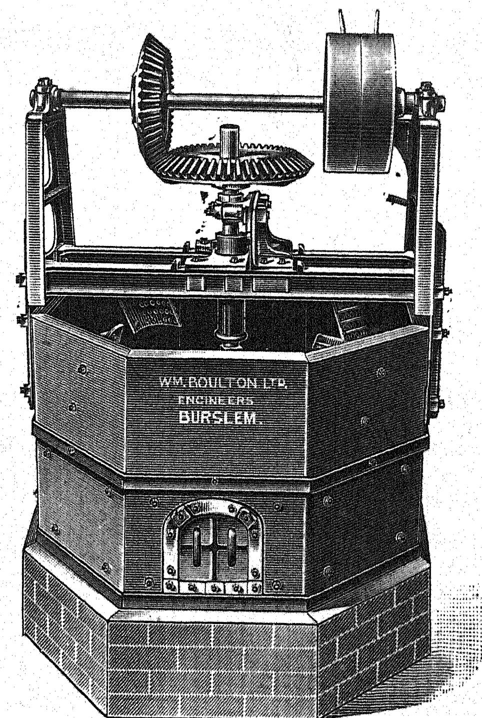


FIG. 202B.—Boulton's type **D** clay-blunger for clay of rough nature containing stones and other hard substances.

works, is advocated by S. G. Burt, of Cincinnatti. (See *Trans. A.C.S.*, vol. v. p. 348.)

Dusts.—If the dust is to be ground between mill-stones, the clay-bodies must be dried quite crisp, to enable the mill to grind efficiently without clogging; but if the dusts are to be obtained by means of disintegrating machines, the body-clays need not be so perfectly dry before treatment.

In the case of disintegration, the dried clay is laid upon a clean tiled floor and water cast over it by a workman who has learned to judge of the proper quantity of water required, and who carefully avoids excess or deficiency.

The damped material is then cast into the machine, by which it is first broken down small and then propelled by a spiral conveyor into a hollow drum of lenticular form, in the interior of which beaters are working at terrific speed, which disintegrate the clay into powder and force it through grids or sieves, whence it falls into heaps or bags as desired. It is necessary to sieve the dust to ensure that all the particles are as nearly as can be of uniform size.

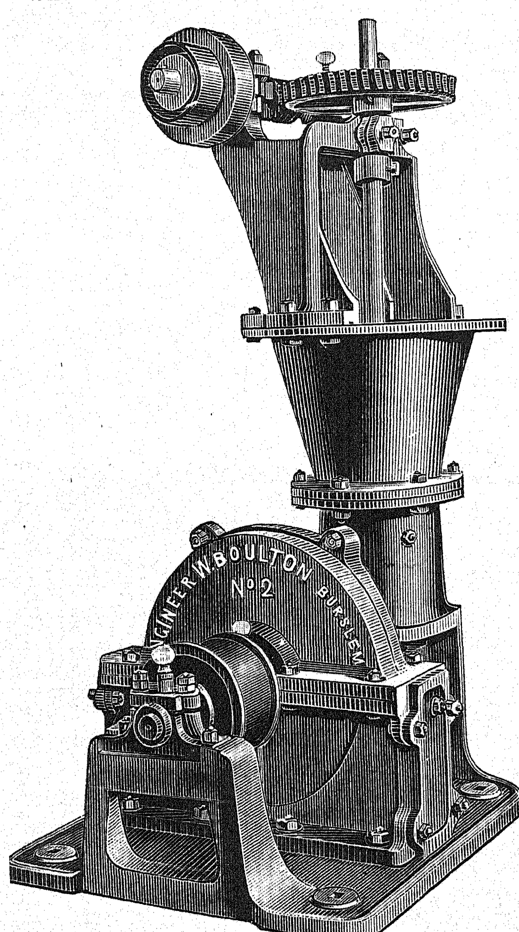


FIG. 203.—Boulton's patent damped-clay pulverizer or dust-mill.

The plaster beds for damping dusts when they have been ground between mill-stones may be formed as indicated in the fig. 204. Usual sizes are 15 feet by 3 feet, or less. The section sketched shows a plaster bed 4 inches thick of plaster, the edge of upper surface being tiled round the dust-space as shown.

When such beds are about to be used, water is thrown upon the plaster surface, until a considerable quantity has been absorbed. After a time, when this has equalized itself, the ground dry clay-dust is lightly spread upon the surface of the plaster to a depth of 3 or 4 inches, and allowed to remain for a time, until it has absorbed enough humidity to press properly.

When the dust is taken off the damping-bed it should be passed through sieves about 8^s, 10^s, or, when wanted very fine, 12^s mesh, and placed in bins for mellowing, carefully labelled. Excessive damping or unevenly damping the dust may cause it to stick to the dies and not deliver well; on the other hand, unless the dust is sufficiently humid, it is too light under the press, and air becomes occluded, or the dust has not sufficient cohesion, and "windblown" tiles result. The defect is perhaps also induced by introducing excess of kaolin in the body, or by grinding the dust too finely.

Again, too newly prepared or unmellowed dust is said to cause freckling or veining of the tile surface.

As clay dust is very injurious to health, every possible precaution should be taken to prevent it getting into the lungs. With damped dust this danger is, of course, greatly reduced, but after drying and before damping great risks exist, and whoever is in charge of the dust-mills and damping-beds should wear a respirator, or in some manner protect the nose and mouth most carefully, and not be employed continuously for a long period.

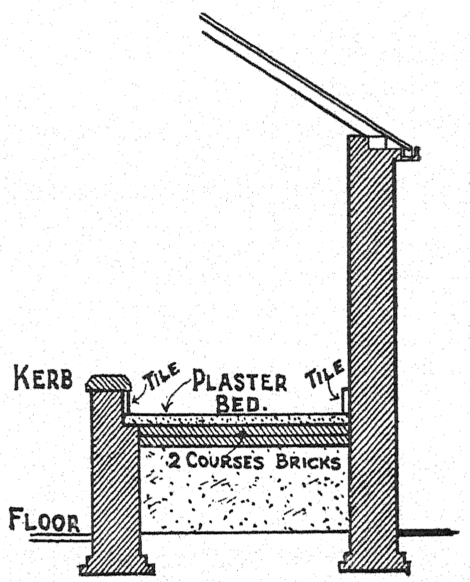


Fig. 204.—Section of tile-dust damping-bed. (*Drawn by W. Campbell, architect, Hanley.*)

Plain Floor-Tile Pressing.—Plain tile-pressing of the kind under consideration is now almost exclusively effected by means of Prosser's dust-clay presses, the clay-dust being compressed to shape in hollow moulds of steel between an upper and a lower steel-faced die by means of a powerful screw. The mould is made any required shape or size, and is entered by a closely fitting top plunger die which is attached to the screw above. The bottom die or plate rests on a supporting frame, the height of which can be modified to vary the thickness of contained dust-clay; this die is also movable vertically, so that when raised it ejects the compressed tile.

Fig. 205 is an illustration of such a screw-press of the horsehead type, and fig. 206 one of the pillar pattern, both of modern construction, as now made by Messrs. W. Boulton, Ltd., of Burslem. Although some tilemakers prefer the horsehead type of press, the writer understands that many more are made of the pillar pattern.

The operation of these presses may be described as follows:—The stop of the bottom die or plate having been set to the proper depth for yielding a tile of the desired thickness—usually half an inch for floor-tiles, for which a depth of dust of about $1\frac{1}{4}$ inch or $1\frac{3}{8}$ inch will be required—and the top die or plunger having been raised to full height, so as to leave the cavity of the steel mould quite clear for operations, the presser wipes the dies clean with a greasy rag. Then from a heap of prepared damp clay-dust placed on the press bench, the presser pushes or scoops laterally into the mould sufficient clay-dust to fill it, and strikes the surface level with a straight-edge. The top die is then lowered,

by a hand-movement of the screw forcing it down into the mould, compressing the dust-clay slowly, so as to allow time for the contained air to escape from the dust during this first pressing. The top plunger die is then rapidly raised again a short distance, and immediately very rapidly and powerfully lowered, so as to impart greater pressure on the contents of the mould, and so form a firm, compact tile.

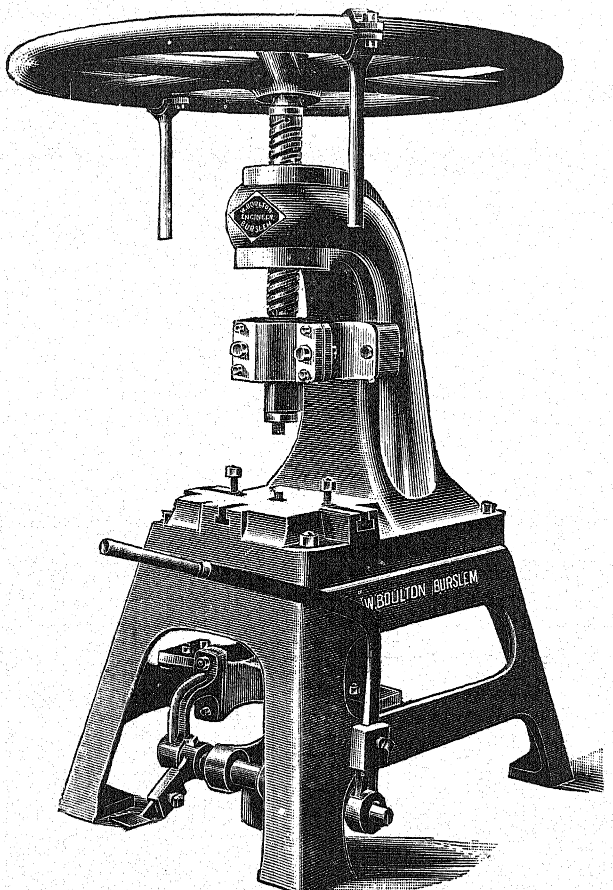


FIG. 205.—Dust-tile press, horsehead type. (*By Messrs. W. Boulton, Ltd., Burslem.*)

The top plunger is then quickly raised to full height, or at least several inches clear of the mould orifice, and the tile forced up and out by foot-gear acting under the bottom plate or die. The tile is now sufficiently hard to bear removing by hand, ready for fettling and placing previous to burning.

The presser then takes off the tile or tiles—for sometimes more than one are pressed at a time—and places them upon a flat burnt setter-tile, from which the attendant removes them and carefully "fettles" each tile, rubbing off the thin feather-edge or burr by means of flannel or fine sandpaper, removing loose dust from the face, and sometimes gently rubbing with wash-leather; finally placing the tiles face to face and back to back on a burnt setter-tile, 6 inches by 6 inches or 7 inches by 7 inches, arranging them geometrically when less than 6 inches by 6 inches, so as to completely occupy the setter-tile to a height of six or eight tiles.

Sand is then scattered on the top of the heap or bung of tiles, and upon this sand a burnt setter-tile is laid.

The heaps or bungs of tiles are then placed on strong boards about 5 feet long by 8 inches wide, ready for carrying to the drying-room.

When the boards are filled they may be either put aside on racks in the pressing-room for a few days to "condition," or carried into a cool part of the drying-room.

The expedition with which these powerful screw-presses are operated can be imagined from the fact that in some instances 6-inch by 6-inch tiles are pressed at the rate of eighteen hundred a day from one machine.

For the sake of economy, small sizes, such as 6 inches by 2 inches, 6 inches by $1\frac{1}{2}$ inch, 3 inches by 3 inches, $2\frac{1}{8}$ inches by $2\frac{1}{8}$ inches, $1\frac{1}{2}$ inch by $1\frac{1}{2}$ inch, 1 inch by 1 inch, and diagonal halves of tiles, are now made two or more at a time, in double or multiple dies, with one or more dividers fixed in the bottom plate, and corresponding recesses cut into the upper plunger die.

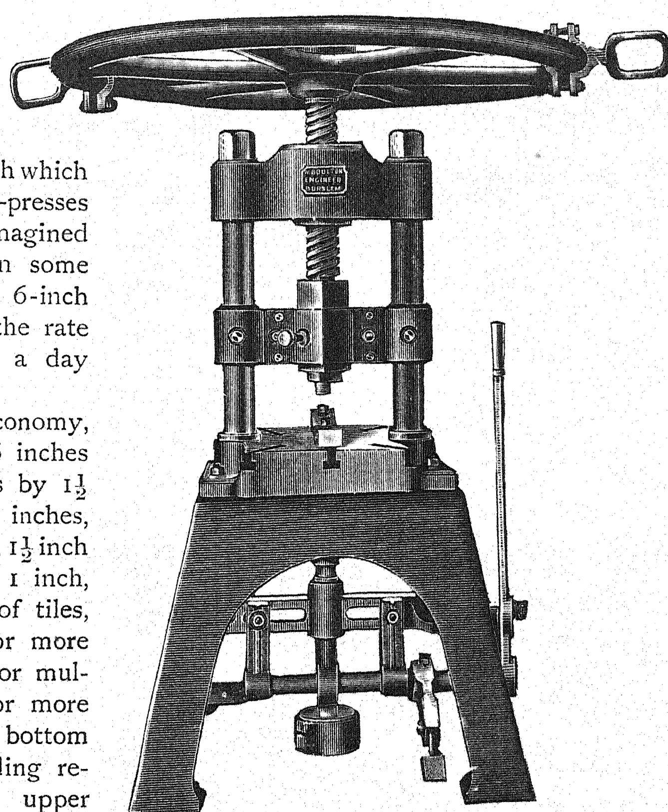


FIG. 206.—Dust-tile press, pillar pattern. (*By Messrs. W. Boulton, Ltd., Burslem.*)

Small presses can be worked by two persons (a woman and a girl), but the larger presses for 8-inch by 8-inch tiles require three operatives to work them efficiently.

The approximate daily output of the common sizes from one machine is stated to be as follows:—

$1\frac{1}{2}'' \times 1\frac{1}{2}''$ to $2\frac{1}{8}'' \times 2\frac{1}{8}''$,	3500 per day	See Boulton's Machinery List.
$3'' \times 3''$,	3000 ,,	
$4\frac{1}{4}'' \times 4\frac{1}{4}''$,	2400 ,,	
$6'' \times 6''$,	1800 ,,	
$8'' \times 8''$ to $6'' \times 12''$,	1200 ,,	

These figures, however, appear considerable; a rate of production of

three or four a minute can scarcely fail to put undue strain upon the operative.

By this dust-clay process much of the contraction associated with plastic or moist clay methods is avoided, and consequently less loss occasioned; yet there is still considerable shrinkage during drying and burning, and allowances have to be made in the sizes of dies and moulds to compensate this.

Different kinds of ceramic bodies or clays contract differently, and therefore allowances for shrinkage must be varied accordingly.

The shrinkages of ordinary English tile-bodies are approximately as under:—

(*a*) Flooring tile-bodies, one-sixteenth.
(*b*) Vitreous tile-bodies, one-ninth.
(*c*) Glazing tile-bodies, one-twentieth or one twenty-fourth.

That is, of course, when these bodies have been suitably burned to the usual degree of firmness and hardness.

To find the required size of metallic mould for a given size of finished burnt tile, the calculation may be as follows, x being the required size of die or mould, and 3 inches by 3 inches the given size of tile, taken as a simple example:—

$$\begin{array}{ll}
(a) & 3+\tfrac{1}{16}x = x, \ \therefore\ 3 = \tfrac{15}{16}x, \ \therefore\ 48 = 15x, \ \therefore\ x = 3\tfrac{3}{15}. \\
(b) & 3+\tfrac{1}{9}x = x, \ \therefore\ 3 = \tfrac{8}{9}x, \ \therefore\ 27 = 8x, \ \therefore\ x = 3\tfrac{3}{8}. \\
(c) & 3+\tfrac{1}{20}x = x, \ \therefore\ 3 = \tfrac{19}{20}x, \ \therefore\ 60 = 19x, \ \therefore\ x = 3\tfrac{3}{19}. \\
(d) & 3+\tfrac{1}{24}x = x, \ \therefore\ 3 = \tfrac{23}{24}x, \ \therefore\ 72 = 23x, \ \therefore\ x = 3\tfrac{3}{23}.
\end{array}$$

In like manner all other sizes may be found.

Or the rule may be expressed thus:—Multiply the required tile-size in inches by the denominator of the ratio of contraction—16, 9, 24, 20, as the case may be—and divide by the same denominator, whichever that may be, less one.

The sizes of the moulds and dies, however, are not by any means the only factors controlling the ultimate dimensions of the burned tiles.

Shrinkages of bodies vary among themselves, those containing high proportions of silica usually being large size when burned; yet that again depends to a great extent on the manner of burning, for tiles made of the same clay-dust, in the same mould, and burned in the same biscuit oven, but in different parts of the oven, will vary in size perceptibly.

As may have been observed, in the case of vitreous-bodied tiles much larger allowances both in area and depth of dust must be made to compensate the abnormally great shrinkage of such bodies, and this should be borne in mind when calculating the cost of various tiles.

The comparatively large dies needed for vitreous tiles may sometimes be cut from ordinary ones which have worn too large for their proper duty.

Minute vitreous tesseræ may be made either by pressing them of various

shapes, one hundred and forty-four at a time, by means of a dust-encaustic tile-press, and burning the product buried promiscuously in loose silver-sand in saggars; or by chipping vitreous tile strips (3 inches by ½-inch by ¼-inch) into fragments of desired shape.

Messrs. W. Boulton, Ltd., of Burslem, make a small mosaic-tile cutting-machine (fig. 206A) specially designed and constructed for the purpose of cutting up scrap fired tiles for use in mosaic work; this must be a very useful and economical manner of dealing with otherwise waste material.

When the size of vitreous tiles is larger than permits of their being placed in sand promiscuously, the tiles, after fettling, should be placed face to face and back to back, with a scattering of fine clean calcined silver-sand between both faces and backs of every tile to keep them separate, or at least easily partable and uninjured during firing. An exception to this, however, must be made in case of rose-pink vitreous tiles, which require a special mode of placing, as described by the recipe.

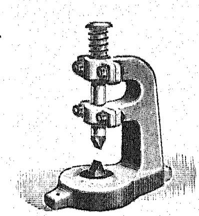


FIG. 206A.—Mosaic-tile cutter. (*By Boulton, Ltd.*)

The composition of vitreous tile-bodies should not be excessively fusible, otherwise the tiles may become warped or blistered, or adhere together during burning, and so cause irreparable loss. Burning, too, must be done carefully if such disasters are to be escaped.

Plastic or Slipped Encaustics.—Figured tiles, incrusted tiles, encaustic-inlaid tiles, or, as they are often called, "encaustics," may now be made by either of two methods, viz., from plastic clay or from dust-clay.

Plastic encaustic-figured tiles were made in England during the mediæval period, but upon the dissolution of the great religious establishments the art of the ornamental-tile maker fell into disuse.

About seventy years ago, however, as we have already seen, Samuel Wright, of Shelton, invented a method of making this kind of tiles, and by its means manufactured a considerable quantity; afterwards he entered into agreements with others to work his invention.

The most eminent of these were Messrs. Minton & Boyle, and Messrs. Copeland, of Stoke-on-Trent; and the art was brought to such perfection by 1844 that Dr. Garner then wrote:—"The tessellated tiles now so much used for the pavement of churches, halls, etc., are made of different-coloured clays, commonly black, red, and yellow. . . . When laid down the effect is beautiful, resembling the richest pattern of the loom." (*Natural History of the County of Stafford*, p. 496.)

Since that time Wright's process has been almost entirely superseded by later inventions; but plastic or slipped encaustics are still made when elaborate and intricate patterns of many colours are required.

As now conducted, the process may be described thus:—A model of the

desired tile is prepared having the figure in relief, due regard being paid to the anticipated shrinkage; from the model a master-mould is prepared in plaster of Paris, having the figure or pattern in intaglio; when this has dried and hardened, working moulds of plaster of Paris are made, having the pattern in relief. These are surrounded by metallic frames (fig. 207), upon which are small studs, corresponding to holes in an additional metallic frame which is attached after the first layer of clay has been inserted.

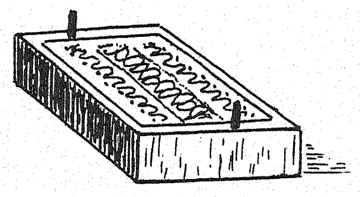


FIG. 207.—Plaster mould for encaustic-tile making.

A layer or "bat" of cane-coloured clay is usually first pressed upon the plaster working-mould; then the additional metallic frame or extension mould is put on, so as to provide depth for the main body of the tile, and this is almost filled with commoner quality of clay, usually coarse red clay; upon this a backing of cane-coloured clay is pressed, to compensate the other layer of similar clay, and the whole is then brought under a hand-press, and after pressing is placed aside to stiffen.

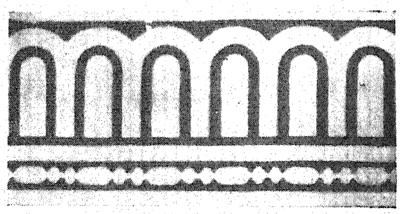


FIG. 208.—Red and buff encaustic tile, 6 inches by 3 inches.

When the necessary degree of stiffness has been attained, the tile is removed from the mould, the face now showing the figure in intaglio. Into the recesses of this sunken pattern stiff slips of coloured clays are poured according to the design, and the embryo tile again laid aside to "condition" or harden.

FIG. 209.—Red and buff encaustic tile, 6 inches by 6 inches.

Afterwards the surface is scraped level by steel straight-edge tools, and the pattern exposed in sharp clear outline, the ends and sides of the tile being made true to shape at the same time. Drying is then finally completed, and the tile afterwards burned. Slight modifications of the process are made occasionally to attain special effects; for example, buff or black encaustic-figured tiles may be made in a simpler manner, by forming a plastic tile of black clay upon a mould having the figure in relief; then, when this tile is removed from the mould, buff clay-slip of suitable composition is poured

into the recessed pattern, dried, scraped level on the surface to reveal the figure, and burned (see fig. 210).

By other modifications of a more or less intricate nature, elaborate designs, such as that of the encaustic-figured tile on Plate XXXVI., are produced. In some of these, ceramic compositions known as "jasper" body-slips are used, giving rise to patterns in rich blues, cameo-like whites, and very beautiful pinks and greens. The jasper slips slightly vitrify and fill up the recesses with a smooth, glassy-surfaced, and lively colour.

Langenbeck's notes under this heading are well worth repeating:—"The question of shrinkage is most exaggerated in the case of encaustic tile whether made plastic or of dust-clay. In these the coloured clays forming the design are inlaid in the clay making the body of the ware. As the product must be absolutely level, the least difference in the shrinkage of the several clays, both in the drying and burning, would unfailingly warp the tile, either causing them to 'buckle' or 'dish.' In this manufacture it is also absolutely necessary that each coloured clay require the same heat and attain one equal hardness with the others; for it must be possible to inlay any combination of the colour-scale into the same piece, and therefore occupy the identical position in the kiln. Advantage, therefore, cannot be taken of the greater or less difference in temperature that always exists between certain parts of a kiln for burning particular colours, as is always done where individual pieces are made of but one mass." (*Chemistry of Pottery*, p. 152.)

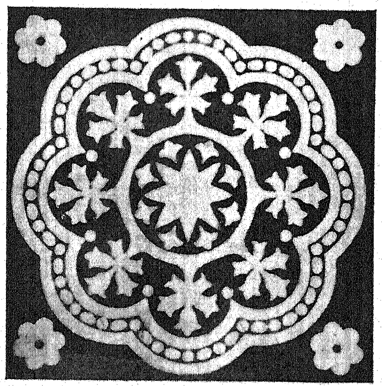


FIG. 210.—Buff on black encaustic tile, 6 inches by 6 inches.

Dust Encaustics.—The adaptation of the dust-clay process to the manufacture of figured or inlaid tiles, now so generally in operation, is substantially the one invented and patented in 1863 by William Boulton and Joseph Worthington, of Burslem. (Patent No. 2176, 3rd September 1863.)

This method of inlaying is the reverse of the old plastic method. In the latter, the body of the tile is first formed with depressions for the pattern, which is put in by means of coloured clays afterwards; whereas in this dust-clay encaustic-figured tile-process the figure or inlay is first formed on the face of the bottom die, and afterwards the body of the tile is added.

Boulton & Worthington's original description scarcely tallies with the usual procedure of to-day, probably because experience has evolved expedients for curtailing the number of operations slightly.

For simple figures in one colour, other than that of the tile-mass, the process may be described as follows :—The press (fig. 211) differs from those used for making plain tiles ; instead of a fixed metallic mould, the mould is movable, both vertically and horizontally, by means of special gear.

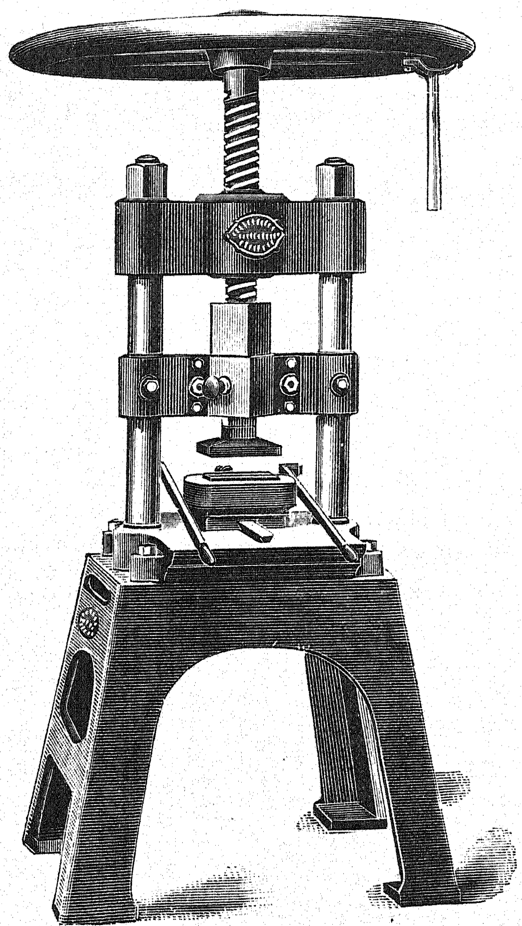


FIG. 211.—Encaustic-tile press. (*By W. Boulton, Ltd., Burslem.*)

The pattern is perforated through a brass plate ("A," fig. 212), which is usually about three-sixteenths of an inch thick and of sufficient superficial area to extend over two sides of the mould. Holes drilled through each end of this plate admit corresponding studs on the mould rim, and enable it to be quickly fixed in exactly correct position ; this is called the pattern-plate.

The pressing-plate ("B," fig. 212) is of similar size, but upon it the figure is formed in high relief, say about three-eighths of an inch, fitted so as to pass exactly through the perforations in the pattern-plate, and protrude through it fully one-eighth of an inch, as indicated in "B A B," fig. 212.

By the courtesy of Messrs. T. & R. Boote, of Waterloo Tileworks, Burslem, photographs of the process in actual operation have been obtained. Fig. 213 illustrates the encaustic dust-tile press, with the mould directly under the vertical screw, and with the bottom die projecting about a quarter of an inch above the surrounding mould-box. Fig. 214 illustrates the same press with the mould-box drawn forward toward the operator ready for the pattern-plate, which may be observed in an inclined position leaning against the press pillar on the right-hand side.

Fig. 215 shows the mould with perforated pattern-plate placed in position

on the bottom die; the pressing-plate will be observed leaning by the side of the pillar.

Fig. 216 shows the mould and die, with pattern or figure formed on the die, the pattern-plate and pressing-plate having been removed and again placed aside.

Fig. 217 shows the mould-box pushed back under the screw-press, the annular metallic mould having been raised around the die and dust-clay added to fill it, and the presser in the act of finally pressing the tile.

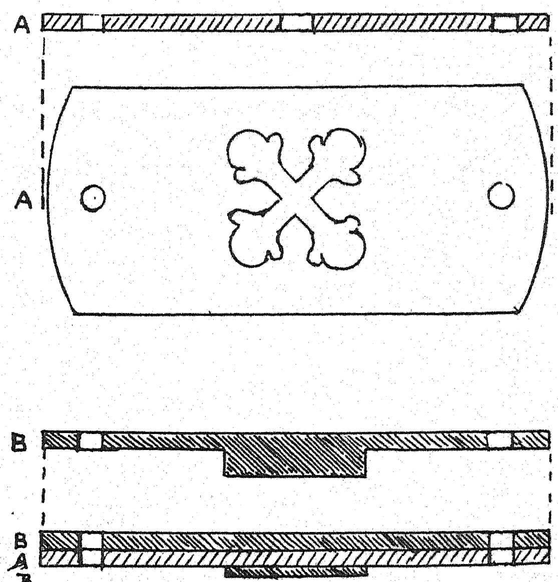


FIG. 212.—Pattern-plate "A" and pressing-plate "B."

These illustrations do not represent every operation in the process, but will be sufficient to convey a correct impression, of it, perhaps, and to explain what follows.

The combined mould and bottom die, or "encaustic-box," having been drawn forward towards the operator, and the annular metallic mould having been lowered until the die appears about $\frac{1}{4}$-inch higher than the surrounding mould, the empty perforated pattern-plate ("A," fig. 212) is laid upon the die in such a position that the studs on the mould-frame pass through the guiding-holes in the pattern-plate, and so retain it in position. The perforations in this brass pattern-plate are then filled in with finely powdered clay of suitable composition and humidity, and of the desired colour when burned, and excess dust struck off the plate. The high-relief pressing-plate ("B," fig. 212) is then inverted upon the perforated pattern in a corresponding position on the die, guided by the studs, and pressed down firmly by hand upon the dust-clay

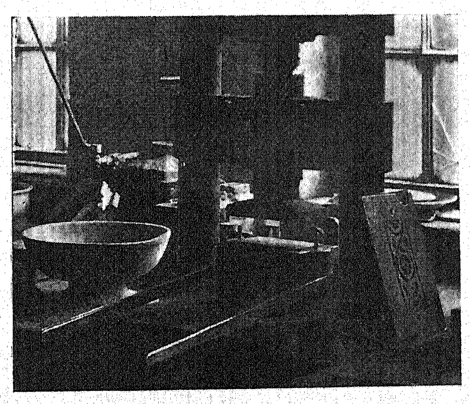


FIG. 213.—Encaustic press.

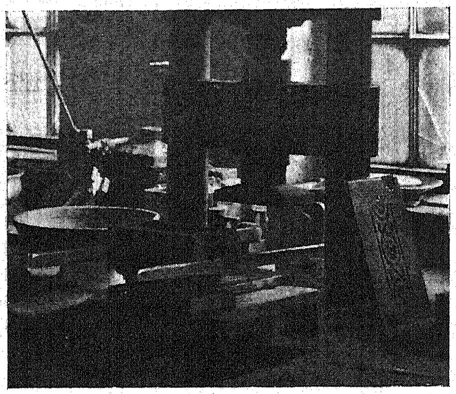


FIG. 214.—Encaustic press.

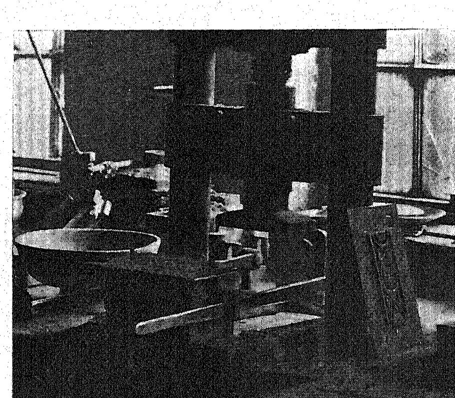


FIG. 215.—Encaustic press.

FIG. 216.—Encaustic press.

occupying the perforations, and lightly tapped by a piece of wood, so as to press the pattern of dust-clay firmly upon the die. Then the pattern-plate is drawn up on the relief of the pressing-plate by hand, the pressing-plate being meanwhile held firmly down on the dust-clay inlay; this operation releases both plates and leaves the pattern formed on the die. The plates are then carefully removed (see fig. 216).

The mould-box or annular metallic mould is then, by means of special gear, raised to the height necessary for containing sufficient dust-clay to form the main body of the tile, and is fixed in position by suitable blocking or supports underneath. The cavity thus formed is filled with dust-clay of the required composition, and the mould-box and die pushed altogether under the press; the top plunger die is then lowered and the tile pressed in the usual manner, and afterwards removed.

Small encaustics, such as $2\frac{1}{8}$ inches by $2\frac{1}{8}$ inches and 3 inches by 3 inches, may be made two at a time; and extra large encaustics, if necessary by reason of the cumbrous weight of the mould-box, may be made with the bottom die fixed as in an ordinary press, and operated by foot-gear.

When more than one colour is to be introduced in the pattern, the perforated plate is laid in position upon the die, and upon it is placed a covering-plate of sheet-zinc, having only certain portions of the pattern

perforated, corresponding both to the perforations of the brass pattern-plate and to one only of the required colours ; dust-clay is then filled into such of the perforations as are uncovered, and the excess struck off; then this covering-plate is replaced by another having perforations corresponding to another colour, dust-clay of the required colour is filled in, and so on until the pattern is completed. When the last-used zinc plate has been removed, the high-relief pressing-plate is applied as before described, the inlay pattern pressed firmly on

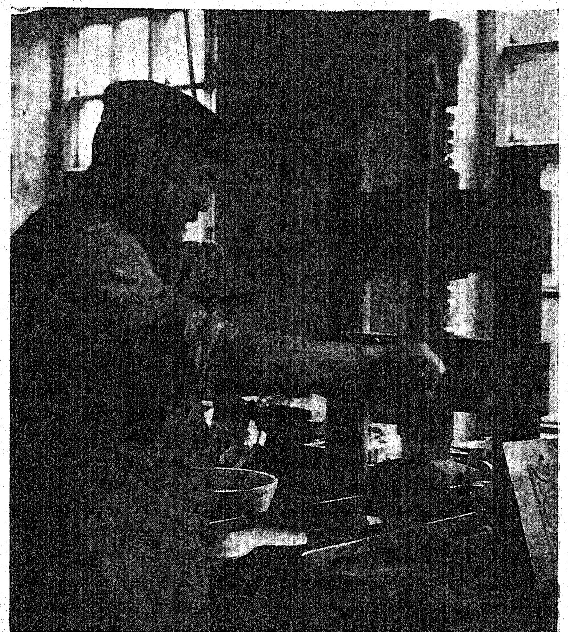


FIG. 217.—Encaustic-tile pressing : finishing operation.

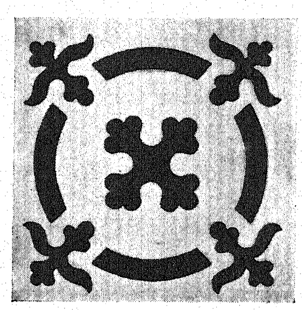


FIG. 218.—Encaustic tile, $4\frac{1}{4}$ inches by $4\frac{1}{4}$ inches.

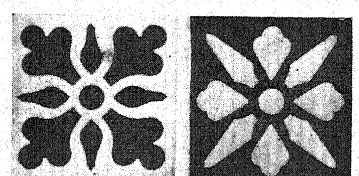


FIG. 219.—Encaustic tiles, $2\frac{1}{8}$ inches by $2\frac{1}{8}$ inches.

the die, the plates removed, mould-box raised and blocked up to proper height, the cavity filled up with dust-clay for main body of tile, and the whole pushed under the press screw and pressed as usual.

When very large quantities of encaustic-figured tiles are required, specially arranged machines are used, by means of which a number of separate operators work the different parts of the process in rotation, each operative dealing with only one coloured dust-clay, and adding only that portion to the pattern.

Drying.—Drying of floor-tiles should, if possible, be effected in closed heated rooms, with moderately numerous but judiciously distributed air inlets and outlets. Strong air-currents or draughts must be avoided, so as to preclude "cutting" or cracking of the tiles during drying as much as

possible. According to the size of the tiles, drying may have to proceed slowly or otherwise: small sizes dry in about seven days; larger tiles require fourteen days or so.

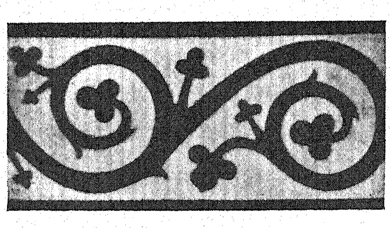


FIG. 220.—Buff on black encaustic tile, 6 inches by 3 inches.

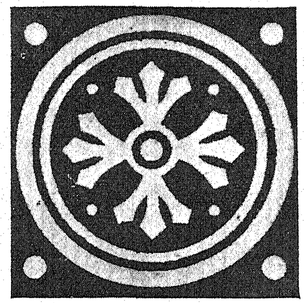


FIG. 221.—Buff on black encaustic tile, 3 inches by 3 inches.

Placing and Setting in.—After drying has been carefully completed, the heaps or bungs of tiles, each having a little sand and a burnt setter-tile on the top to keep them straight and true and to ward off flashing, are placed in saggars, two heaps in a saggar side by side.

If the heaps are eight tiles high and 6-inch by 6-inch area, that would be 4 square feet of tiling in each saggar (3 inches by 3 inches being set four bungs on each 6-inch by 6-inch setter, and $1\frac{1}{2}$ inch by $1\frac{1}{2}$ inch set sixteen bungs on each 6-inch by 6-inch setter).

Vitreous-bodied tiles have to be placed in a similar manner when of sufficient size, except that between each tile a thin sprinkling of fine silver-sand must be scattered to prevent mutual adherence when burning. Small tesseræ may be buried promiscuously in burnt silver-sand in the saggars without either "bats" or "setter-tiles."

Rose-pink vitreous tiles, however, should be specially placed in single layers, face upwards, on sanded setters, no sand being put on the surface. To enable several tiers to be placed in the same saggar, small props are interposed between the setter-tiles. Tiles of this particular colour, however, are perhaps rarely made in larger sizes than $1\frac{1}{2}$ inch by $1\frac{1}{2}$ inch.

The bungs having been placed in their respective saggars, keeping only one colour in a saggar as far as practicable, they should be "set in" in biscuit oven approximately as follows:—

First ring.—Vitreous white under the bags; black tiles in the hottest parts; white and buff in upper parts.

Second ring.—Chocolate, red, vitreous blue and green, and bath-tiles.

Third ring and middle.—Drab and pink floor-tiles and bath-tiles.

Saggars.—The nature of the fire-resisting compositions of which saggars are made having been fully entered into in Chapter IV., it is only necessary

to say here that the saggars themselves may be made either by the various machines in use for the purpose, or by hand in the old way on wooden drum-like moulds. For the tile trade it is desirable that they should be made of more approximately geometrical shape than is the case with saggars for pottery ware, with the object of more economically enclosing and protecting the product, and economizing oven or kiln space. The most usual size of saggar is one that will comfortably hold two columns or bungs of tiles six or eight tiles high, each bung of an area of 6 inches by 6 inches.

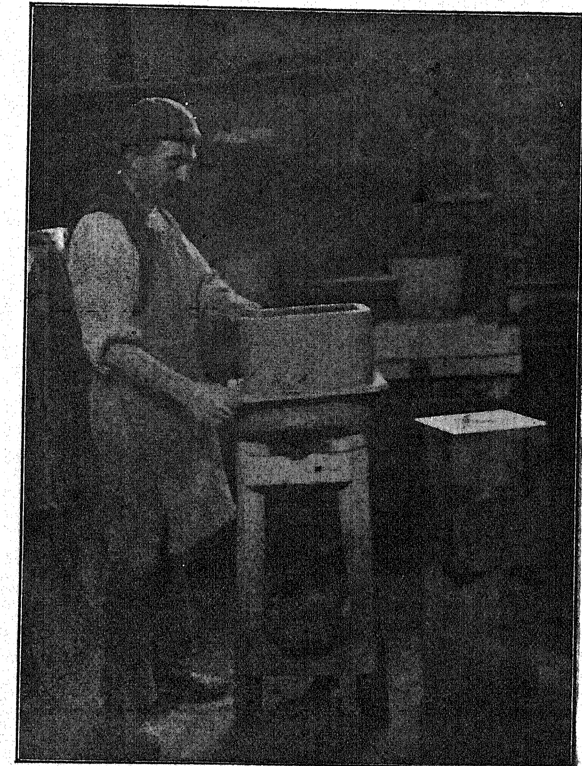


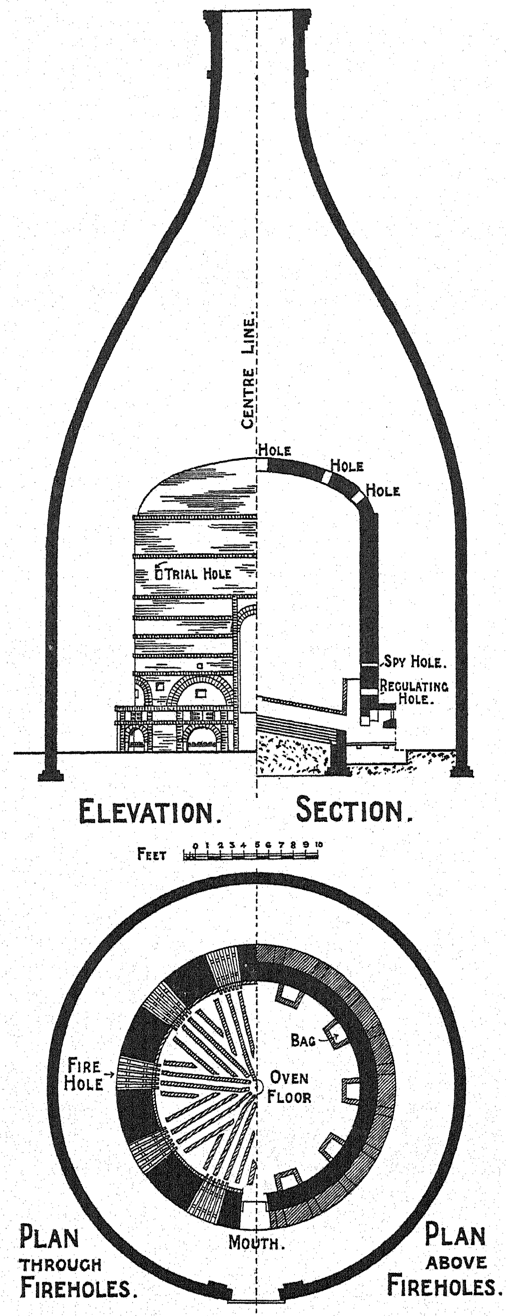
FIG. 222.—Saggarmaker at work. (*By permission of Messrs. Carter & Co., tile manufacturers, Poole.*)

By the kindness of Messrs. Carter & Co., of Poole, we are able to illustrate a tile-saggar maker in the act of finishing a saggar; which, it may be observed, is approximately of more geometrical form than ordinary potters' saggars.

There are several machines for saggar-making, such as Minton's, Wenger's, the hydraulic, and the more recent invention by Mr. E. W. Leigh, of Cobridge, for which various advantages are claimed.

In the works of the Pilkington Tile Co., at Clifton Junction, near Manchester, the saggarmaking department is reported to be especially interesting. The life of the saggars at these works is said to be thirty to thirty-five times, as compared with an average of about fifteen in the Potteries. The whole of the work of saggarmaking for supplying nine ovens and twenty-two kilns is said to be done by one man and a boy. (*Staff. Sentinel*, 29.3.04.)

Biscuit Oven.—When a works is erected specially for the tile trade, certain special provisions can be made in the way of ovens. The biscuit kiln or oven



BISCUIT OVEN.

W. CAMPBELL, ARCHITECT, HANLEY.

FIG. 223.

can then be built rather smaller than those for general earthenware, with the object of giving better control of the contents during the firing. An ovenful of dust-tiles in the clay state represents a very dense, compact mass of great weight. Such a mass requires firing differently from an ovenful of hollow-ware vases, ewers, and jugs. Where possible, the oven should have a more strongly built foundation and bottom, and be of greater strength for its size in every way. It is not only that greater weight has to be carried while in an incandescent condition, but to enable the fire to thoroughly and completely penetrate such a large, almost solid mass of clay goods, the fire must necessarily be more slowly raised to the required temperature, and held there for a longer period.

In addition, it is essential to remember that in a tile biscuit oven many ceramic bodies of essentially different nature are often burned at one time, such as red-burning, buff-burning, white-burning, semi-vitreous, and vitreous.

Burning or Firing.—The burning or "firing" of a biscuit ovenful of flooring-tiles has been variously described by practical men.

By grouping the descriptions mentally and filling up little omissions, a fairly correct impression of actual practice will be acquired.

(*a*) Smoke the kiln with slow fires of fine coal for twenty-four hours on Saturday: relight the fires early on Monday morning; get the heat up very gradually for the first two days and nights, arriving at the climax of heat, say, by the following Friday evening. Then cool the oven slowly during Saturday, Sunday, and Monday, and draw the ware on Tuesday.

(*b*) Another expresses his directions for firing very tersely thus:—"A biscuit kiln for flooring-tiles should have two nights' smoking and four nights' firing."

(*c*) Another fixes the time of firing for a tile biscuit oven at one hundred hours.

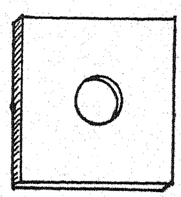


FIG. 224.—Fireman's trial.

(*d*) Firing by means of natural gas in the United States is said to occupy four or five days and nights, including twelve hours' smoking. Gas is said to require more time than coal, because it is so keen.

For trial-pieces the firemen ordinarily use a number of $2\frac{1}{8}$-inch by $2\frac{1}{8}$-inch tiles made of black tile-body, but having a hole pierced through each to facilitate its withdrawal for examination during the progress of the burning (fig. 224). These are placed in trial saggars in the upper and lower parts of the oven or kiln, in each quarter or suitable position, and in such a manner as to be accessible from without through small apertures, which can be closed or opened temporarily at will. The kiln must be fired until all the trials in all parts assume their correct tint and size, as measured upon a special gauge. Black body is used because it is particularly sensitive to differences of

temperature, and at the same time hardy enough to bear withdrawal from the kiln while incandescent.

But Seger cones, Holdcroft's thermoscope bars, and similar guides are coming more and more into use for judging the burning of kilns. For a tile biscuit oven Mr. Watkin advises pellets 21 to 29=1110° C. to 1270° C. (see Chapter V.).

From a very instructive paper by Professor Orton, entitled *On the Rôle played by Iron in the Burning of Clays*, we cull the following notes bearing upon this topic of firing of kilns:—"We have now seen that the occurrence of iron in clays is so varied as in itself to suggest a cause for the complexity of results which practice demonstrates. And there is no question that much of the richness and variety in clay products does come from just this fact. But the treatment which the clays receive in burning is a matter of fully equal concern to the clayworker, because the strength, durability, beauty and color, texture, in fact the whole quality of his product, is affected or controlled thereby. It is a matter of even greater concern, because it is largely under the control of the clayworker himself, and is thus a direct key to commercial success. . . . . Clay-burning is chemically a most complex process; it consists of a series of reactions overlapping one on the other in such a manner that one can never trace the exact beginning or end of any single one. In general, we may divide it up into three principal kinds of reactions, and these divide the burning process roughly into three corresponding stages.

"*First.*—The dissociation of materials which are unstable at high temperatures, and the expulsion of the volatile portions from the mass of the clay.

"*Second.*—The transformation of the non-volatile elements from less stable into more stable forms by absorption of gases from without the mass.

"*Third.*—The amalgamation at an elevated temperature of the various residual inorganic substances left by the two preceding reactions into a more or less perfect silicate compound. . . . . The division of the burning into these three periods is of course arbitrary, since the reactions overlap, and at no time can it be said that one process only is going on."

With regard to the *dehydration period*, Professor Orton observes:—"The reactions of this period are only the preliminaries by which the minerals of the clay are brought into condition for the final combinations which culminate in the finished ware. The reactions chiefly are:—

"(*a*) Expulsion of hygroscopic water from the clay.

"(*b*) Combustion of carbonaceous matter.

"(*c*) Distillation of S from pyrites, leaving FeS.

"(*d*) Dehydration of kaolinite, ferric hydroxide, and other hydrous minerals.

"(*e*) Decarbonization of carbonate minerals. . . . .

"Water is vaporized at 100° C., and theoretically cannot exist longer in the clay in the free condition after that temperature is reached. But practically

the pores of the clay-ware retain it obstinately until temperatures considerably in excess of 100° are reached in the general atmosphere of the kiln. The kiln is hardly to be considered dry until the atmosphere of its coldest part has reached 150° C. The power for ill which this process exerts lies in the delaying of other processes. . . . . No oxidation or dehydration can occur while the mechanical water is present; and further, no sensible headway can be made in heating the ware up until the water is gone. . . . ."

With reference to the *oxidation period*, Professor Orton tells us that it has been his experience "that the difficulties and losses in the burning of crude clay-wares are more largely referable to mismanagement of this phase of the burning than to any other. . . . . Thousands of dollars would be saved annually if clay-burners could be brought to see that in passing above this temperature line they are taking an irrevocable step, and that clay, not well oxidized at that time, is practically sure to be spoiled. . . . .

"There is but little probability of the clay oxidizing after 1000° C. is reached. In fact, but little of account happens after 900° C. Hence, for all practical purposes, we may say that when ware is not oxidized at the right time it will not be oxidized at all. . . ."

Professor Orton mentions an instance where a brick company found it necessary to fire their kilns by first raising the fires to about 900° C., then allowing them gradually to die down to beds of ashes, reducing the draught and allowing the temperature to fall to 600° C., or nearly black. This took twelve or eighteen hours. Then firing up again, the kiln was carried to the finish, the secret of success in this case being long exposure to air nearly free from carbonic acid. Eighteen hours of nearly pure hot air was effective, where three or four days of ordinary oxidizing at red heat had failed entirely to get the FeO all converted.

"Burners generally have a superstition to the effect that it is fatal to ware to allow the heat to drop back after once raising it to redness. There are good reasons in some cases why this should be avoided; but in dealing with such a case as this it is practically the only way to get good results."

Further on in this paper it is noted that at the conclusion of the oxidation period, "If the work has been correctly done, the ware will be uniform in color in its whole cross-section. . . . . On the other hand, if the clay be improperly oxidized, it will show on its fracture a spot, furthest from the exterior, of different color from the exterior of the ware. This new color is dark. The size of the spot will depend on the completeness or incompleteness of the work. The larger it is, the more certain it is to ruin the ware subsequently. . . . .

"In all that has been said so far, the allusions to trouble ensuing from incomplete oxidation have been frequent, but little has been said in explanation of what these troubles are. The reason for this reticence is that the real development of the trouble occurs only in the vitrification process. If the

burn ended at 1000° C., then all of this discussion would be valueless. But hidden away in this apparently unimportant dark-colored spot are half the potential sources of trouble. . . . ."

The vitrification period is outlined by Professor Orton thus:—"The first change is thought to be a sort of condensation or shrinkage in itself of the kaolinite base of the clay. This precedes silicate formation, at least for the most part. Then the caustic basic oxides lime and magnesia begin to react on the dehydrated clay, forming silicates and aluminates. These soon give way to other compounds, which bring the finest of the free quartz into combination. The feldspathic fluxes also begin to work, and thus from one combination to another the work proceeds, building up one compound only to form another from it as the temperature increases. . . . .

"Vitrification among clayworkers is a technical term. It does not mean . . . . that the clay has become converted into an absolutely homogeneous or glass-like solid. . . . . Complete vitrification means that stage of a clay's burn where it becomes densest and strongest. All clays pass in burning through a series of stages, and are progressively harder, stronger, and denser up to a maximum; after that they begin to fall off . . . . until they finally become a worthless vesicular, slag-like mass, devoid of useful qualities. The culminating point of excellent, though hard to define, is not hard to recognize. And while it does not by any means stand for the same qualities in any two clays, it is clearly defined to the practical man in dealing with each clay by itself. . . . .

"The point of complete vitrification makes an excellent place to divide our discussion, for the reason that no one voluntarily passes it in producing clay-wares. . . . . Those changes which mature before or by that time are all familiar ones, which must be reckoned with daily. The changes which follow are distinctive changes, to be avoided if possible."

As to the reasons why clay-ware which is not oxidized at the proper time is never oxidized, the Professor asserts that, "first, the porosity of the ware rapidly diminishes as the temperature rises. Some clays mature wonderfully quickly in the temperature range between 1000° and 1100°. . . . . Second, the composition of the fire-gases becomes less and less fit to oxidize the ferrous oxide as the temperature increases." . . . .

"Free oxygen *in large excess* is necessary to rapid oxidation. But as the temperature of the kiln increases, the products of combustion will stand less and less dilution with free air without becoming too cool. As the temperature reaches 1200°, it becomes practically impossible to admit any excess air, or rather the combustion fluctuates between oxidizing and reducing with each baiting of coal, so that the average gas produced is neutral. Where temperature of Cone 8 or above is used, the reducing action predominates. Where for any special ware it is essential to maintain oxidizing conditions to a high temperature, 1300° or above, it is necessary either to so construct the firebox and

bags as to obtain a regenerative effect on the air-supply, and thus decrease its cooling effect, or to use gas fuel or some similar device. With cold air and solid fuel it is very difficult, if not impossible, to prevent occasional reduction at even 1200° C." (*Trans. Am. Cer. Soc.*, vol. v. p. 377–420.)

Reverting to the consideration of the preliminary stage of the burning, viz., the dehydration or driving off of the remnant of hygroscopic moisture and the whole of the combined water, a writer in the *British Clayworker* (August 1903, p. 159) observes:—"Some 2 per cent. at least of moisture will remain in ordinary air-dried clay, together with nearly twice that amount of water in such a state of combination with the clay that it cannot be removed by a temperature of less than 250° F. . . . . Assuming, then, that only 7 per cent. of water (both as moisture and in the combined state) be present in the goods, this is equivalent to 156 lbs. of water for every ton of clay in the kiln; and as each pound of water forms, roughly, 27 cubic feet of steam, this means that more than 4200 cubic feet of steam (per ton of clay-ware) must be moved before the kiln reaches even a dull red heat. These figures show . . . . how necessary it is to have sufficient 'ventilation' in the kiln, and as a rapid current of air cannot be drawn through the kiln without a great risk of cracking the goods, it follows that time is required for the first stage of burning. Exactly how long the 'smoky fire' should be used to dry the kiln will depend on the nature of the kiln and the goods to be burnt."

Firing with Natural Gas.—In the United States of America certain districts within, or within economical distance of, regions yielding natural gas make use of the gas for lighting, heating, and power-generating purposes—among others, for burning tiles.

The United States Encaustic Tile Co. of Indianapolis, The Star Encaustic Tile Co. of Pittsburg (Pa), The Columbia Encaustic Tile Co. of Anderson, and The American Encaustic Tiling Co. of Zanesville are said to use natural gas for burning; and Mr. T. W. Harrison, of Hanley, who recently visited East Liverpool, is reported to have said that the whole of the potting trade there is carried on by means of natural gas. (*Pottery Gazette*, March 1903, p. 282.)

Mr. Samuel Keys, founder and superintendent of The Star Encaustic Tile-works at Pittsburg, states that they use natural gas for all purposes, and have not used a pound of coal for years. He explains that the wares are burnt in saggars, and the construction of the kilns is the same old style of kiln as used in Staffordshire; the only change required being to build up the openings and insert the gas-pipes. A regulator controls the pressure of gas, and heat is gained or otherwise by the setting of the regulator. He says it never varies, is as true as clockwork, and they can time the burning to a nicety; that burning by natural gas is a great labour-saving system; and that gas can be

used in any kind of kiln, either up-draught or down-draught, without any alterations except at the fire-mouths. When using gas no night man is required; you simply set the valves and let it go. Mr. Keys adds that it takes from four days and nights to five days and nights to burn their tiles with natural gas, including twelve hours' smoking; also that gas requires more time than coal with their body, because gas is very keen

The great gas-fields are situated in Western Pennsylvania, West Virginia, Ohio, and Indiana, and the gas is piped to different manufacturing centres, costing at Pittsburg 15 cents per 1000 cubic feet. Many companies make a business of drilling for gas and supplying the public. One of these, "The People's Natural Gas Co., of Pittsburg," have just completed a gas-line from their West Virginia wells to Pittsburg, a distance of sixty-five miles of 20-inch pipe.

In the U.S. Geol. Survey Report on the *Mineral Resources of U.S., 1901*, it is claimed that "As a source of heat, light, and power natural gas is unexcelled from the moment it reaches the surface of the earth, at the mouth of the well, until it reaches the farthest consumer at the end of the pipe-line. No preparation is necessary for its combustion, and no residue is left. It needs only to be mixed with the proper amount of air, and to have the combustion started by a naked flame or by an electric spark, when it will appropriate to itself the proper amount of oxygen. As a source of heat it is unrivalled in the household, as it is also in the workshop. . . . . As a source of power it stands at the head of the list for economy, both as to expense of installation and expense of operation. . . . . The value of the natural gas sold in 1901 was greater than that of any previous year. . . . . There were 11,297 wells producing natural gas at the close of 1901. . . . . Nearly 800 miles of pipe laid during 1901 . . . . brought the total up to 21,848 miles of natural-gas mains. . . . ." (*Min. Res. U.S., 1901*, pp. 613–615.)

A certain degree of care, however, is necessary when using natural gas; for on p. 631 of *Mineral Resources of United States, 1901*, we read, with regard to oil-wells, that "All the large producing wells when flowing gave out more or less natural gas, which is highly charged with sulphuretted hydrogen, and is very deadly in effect when taken into the lungs in large quantity."

Natural gas, such as that of Grapeville (Pa.), proves on analysis to be a mixture of marsh-gas, ethane, nitrogen, hydrogen, carbon dioxide, carbon monoxide, ethylene, and oxygen. (*Leisure Hour*, 1886, p. 569.)

More recent and exact information, however, has been kindly supplied to the writer by F. H. Oliphant, Esq., of the Natural Transit Company, United Pipe Lines Division, Oil City (Pa.), compiler of the reports on the production of natural gas for the United States Geological Survey. He writes as follows:—

"The analysis of gas from South Western Pa. is as follows:—

"Pennsylvania—Sheffield—

Nitrogen,	9·06	The proportions of C and H in the paraffines were as follows:—	
Carbon dioxide,	0·30		
Hydrogen,	0·00		
Ammonia,	0·00		
Oxygen,	trace		
Sulphuretted hydrogen,	0·00	Carbon,	76·69
Paraffines,	90·64	Hydrogen,	23·31
	100·00		100·00

"Findlay, Ohio—

Hydrogen,	1·64
Marsh-gas, CH_4,	93·35
Olefiant gas	·35
Carbonic oxide,	·41
,, acid,	·25
Oxygen,	·39
Nitrogen,	3·41
Sulphuretted hydrogen,	·20
	100·00

By the aid of drawings and particulars kindly supplied by Mr. Samuel Keys, of Pittsburg, we are able to illustrate one form of kiln used in the United States for burning encaustic tiles by means of natural gas. The plan and elevation have been drawn to scale, as correctly as practicable with the material at hand. The bottom of the kiln is set out with flues in the same manner as adopted in England, with one outlet in centre, with pipe-bungs for centre. The bottom of kiln above the flues is 20 inches lower than the top of the bench, which is 3 feet 6 inches high by 2 feet 9 inches at top. From bottom to top of bags inside the kiln is 3 feet 6 inches. In the crown there is a centre hole 1 foot diameter, and sixteen smaller openings, two to each arch, set in diagonally, each 1½ inch diameter. The outside of the kiln from bench to shoulder is banded with 5-inch hoops, ¼-inch thick. There is no hovel over all, because the kiln is built in a room in the lower part, and is only exposed above a line 18 feet high from ground-level.

It is claimed that there is no dirt or odour arising from the natural gas; the whole room, including the kilns, is whitewashed, thus ensuring clean and healthful conditions not obtainable when coal is used as fuel.

In Canada the gas-producing regions are chiefly in Ontario, where natural gas was discovered in 1889. Two distinct areas have been defined—one in Essex County and the other in Welland County. The greater part of the gas is piped to the adjacent cities of Buffalo and Detroit in the United States. (*Report of Bureau of Mines of Ontario, 1902.*)

But it is not all plain sailing with natural gas. For instance, in *Brick* for

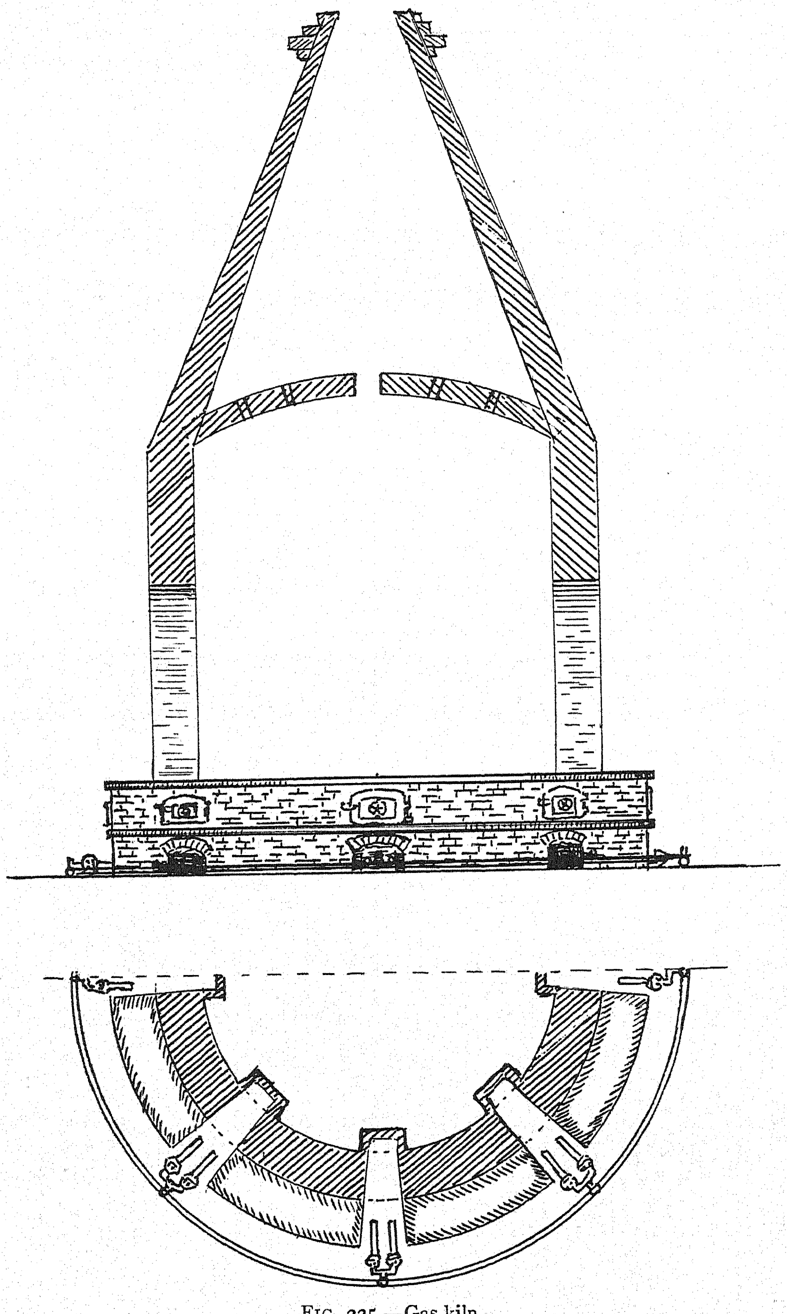


FIG. 225.—Gas kiln.

May 1903, p. 229, we are told that "Almost all the potteries in East Liverpool and vicinity were shut down for several days last month owing to a break in the gas lines making the shortage so much that hardly any of the plants were able to run their factories or fire their kilns." And from the *Report of the Ontario Bureau of Mines, 1902*, pp. 42–44, we learn that several Canadian towns have been placed in unenviable circumstances by failure of supplies.

Natural gas has recently been found and used in the South of England. To those who are not conversant with the facts the following excerpt from the *Birmingham Daily Post*, 6th August 1903, may be interesting:—

"NATURAL GAS IN ENGLAND.

"In the minds of the public, natural gas has always been so intimately associated with the United States that information of its existence in England, for example, comes in the nature of a revelation. In the August number of *Cassier's Magazine*, however, Mr. Inverness Watts tells us that natural gas was discovered in East Sussex as long ago as 1875, when, in making experiments on the temperature in a bore-hole at various depths, and on lowering a light into the bore-tube, an explosion occurred. Among subsequent further discoveries the most important one appears to have been made in 1896 at Heathfield Railway Station of the London, Brighton, and South Coast Railway. The railway company desired to obtain a better quality of water for their engine-tank than that afforded by the present surface-spring supply. Accordingly a 6-inch bore-tube was sunk, commencing at the bottom of a sump 73 feet deep, into which the surface water had been allowed to flow. Gas appears to have been discovered a long time before its inflammable properties were tested, a strong odour of gas having been noticed for some days; but the smell was attributed to the presence of 'foul air' in the bore-tube. At a depth of 312 feet from the level of the permanent way the smell and rush of the gas were so pronounced that (by way of experiment) someone applied a lighted match to it, when a body of flames sprang up, the height of which is variously stated, the maximum estimate being 16 feet. It was extinguished with great difficulty, by means of damp cloths thrown over the mouth of the tube. The gas continued to increase during the remainder of the depth bored. The boring was abandoned at a depth of 377 feet, no useful amount of water having been obtained. The wrought-iron tubes were withdrawn from the bore-hole, with the exception of one length, which still remains in the ground, the tube being continued upward to near the top of the sump. A cast-iron cap has been secured on to the top of the bore-tube, with a ½-inch bend and stop-cock affixed thereto, and Heathfield Station has been lighted throughout by gas from this boring since 1898, consuming about 1000 cubic feet each night. More recently many other borings have been successfully made for natural gas

in various parts of Sussex, and are likely to have an important influence in attracting and developing new industries."

Firing with Mond Gas.—The formation of very wealthy commercial organizations for establishing extensive works for the production of what is known as "Mond" gas on a very large scale, for manufacturing purposes, in many parts of England, and the successful employment of the gas in numerous industries, together with—and more particularly perhaps—the formation of a local company to establish such works in North Staffordshire and adjacent districts, has attracted the attention of potters and tilemakers, and given rise to considerable discussion and many anticipations. Some notice of the matter in these pages therefore will need no apology.

To the question, What is Mond gas? a concise answer is found in a reprint, issued by the Commercial Education Department of the London Chamber of Commerce, of a lecture on *Producer-Gas*, by H. A. Humphrey, Esq., F.C.G.I., A.M.I.C.E., etc. This shows that producer-gas is a gas obtained from coal and steam and air, in such a manner that the whole of the combustible matter contained in the coal is converted into combustible gas, no coke residue being left, only ashes; the yield of gas per ton of coal being about 150,000 cubic feet. It further shows that in the case of illuminating coal-gas, as made for lighting purposes in the ordinary gas retorts, after the coal has been carbonized a coke remains containing about 60 per cent. of the combustible matter of the original coal—the yield of gas being approximately 10,000 cubic feet per ton of coal used, varying with quality and with treatment (see subjoined tabulated results).

COMPARATIVE COMPOSITION, YIELD PER TON OF COAL, CALORIFIC VALUE, ETC., compiled from Roscoe's *Elem. Chemistry*, p. 81; Humphrey's *Producer-Gas and its Application*, pp. 2 and 5; and *Power-Gas and Large Gas-Engines*, p. 74; *Pottery Gazette*, May 1904, p. 563, etc., etc.

	Volume of Gas yielded per ton of coal.	Calorific Value, B.T.U., per cub. foot.	Illuminating Power in candles per 5 cub. feet.	Composition in 100 Volumes.						
				Hydrogen, H.	Methane or Marsh-gas, CH_4.	Heavy Hydrocarbons, C_nH_{2n}.	Ethane, equal to Olefiant Gas, C_2H_4.	Carbonic Oxide, CO.	Carbonic Acid Gas, CO_2.	Nitrogen, N.
	Cub. feet.									
Cannel-gas, .	11,000	?	34·4	25·82	51·20	13·06	(22·08)	7·85	2·07	
Coal-gas, . .	10,000	600	13·0	47·60	41·53	3·05	(6·97)	7·82	...	...
Siemens gas, .	?	?	?	?	5·00	..	...	25·00	?	?
Mond gas, . .	150,000	150	...	29·00	2·00	...	...	11·00	16·00	42·00
Water-gas, . .	...	...	...	48·60	0·40	...	...	44·00	3·00	4·00
Natural gas, .	...	1000	6 to 12	1·64	93·35	...	0·35	0·41	0·25	3·41

Mr. Humphrey states that "Although the calorific value of illuminating gas is nearly four times that of the same volume of producer-gas, yet the quantity of the latter is so much greater that the total available heat-units in the

producer-gas is practically four times as great as with lighting gas derived from the same weight of fuel."

Mr. Humphrey briefly traces the history of this gas from 1840, when scientists were working on the problem in Germany, France, and Sweden, and gives particulars of the Siemens producer, invented in England in 1861. He also illustrates and explains the Dowson gas-plant, which yielded gas suitable for use in gas-engines as direct-power generators.

"There was still need," he tells us, "for a cheap producer-gas of high calorific value and constant quality which could be used both for furnace work and in gas-engines, and Dr. Ludwig Mond was the first to invent a producer capable of successfully treating common bituminous slack to generate such a gas. Dr. Mond was also the first to recover on a large commercial scale the considerable quantities of sulphate of ammonia now regarded as such a valuable by-product in the manufacture of producer-gas from common slack.

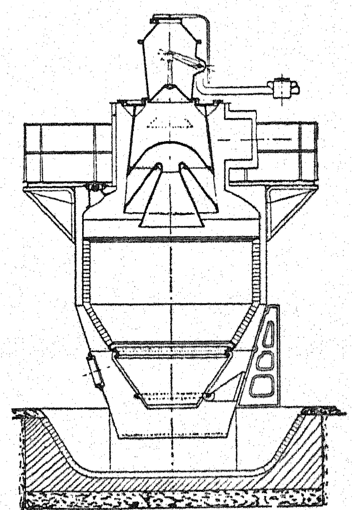


FIG. 226.—Mond-gas producer.

"The Mond producer is shown in fig. 226, from which it will be seen that there is a double casing to the producer, the space between forming an annular chamber, into which the blast is delivered at the top and travels downwards until it meets the conical fire-grate. The fire-bars do not meet at the centre, so that an opening is left, and the burnt ashes form a heap extending downwards into the water-lute, and supporting part of the weight of the fuel above them. The arrangement greatly facilitates the removal of the ashes and the steady downward progress of the fuel as the gas is driven off. There is a measuring-hopper situated over the centre of the producer, and all necessary examination doors and poke-holes. Each producer of ten feet diameter is capable of gasifying a ton of fuel every hour. The fuel charged into the producer is first measured in the measuring-hopper, and then allowed to fall into an internal bell, where the 'green' fuel is subjected to a partial distillation process before entering the main body of the producer. The products of distillation have of necessity to pass downwards into the hotter zones before they can escape, and the tarry products are thus to a large extent destroyed and converted into fixed gas.

"Owing to the large amount of steam which is introduced along with the air, the temperature in the Mond producer is maintained much lower than in other producers; consequently the ammonia is not destroyed, and the brickwork lining will last for years without repair; also, the temperature is not

high enough to produce those clinkers which have been one of the chief sources of trouble in the earlier producers.

"A diagrammatic view of the Mond plant as a whole is given in fig. 227, which represents a thoroughly up-to-date plant for the manufacture of good quality gas from common slack. Beginning first with the air, you will notice that a positive-action blower is provided for putting the blast under pressure, and the line on the diagram composed of small dots shows the course which the air takes on its way to the producer. It first passes up the air-heating

DIAGRAM OF MOND GAS PLANT WITH RECOVERY OF AMMONIA.

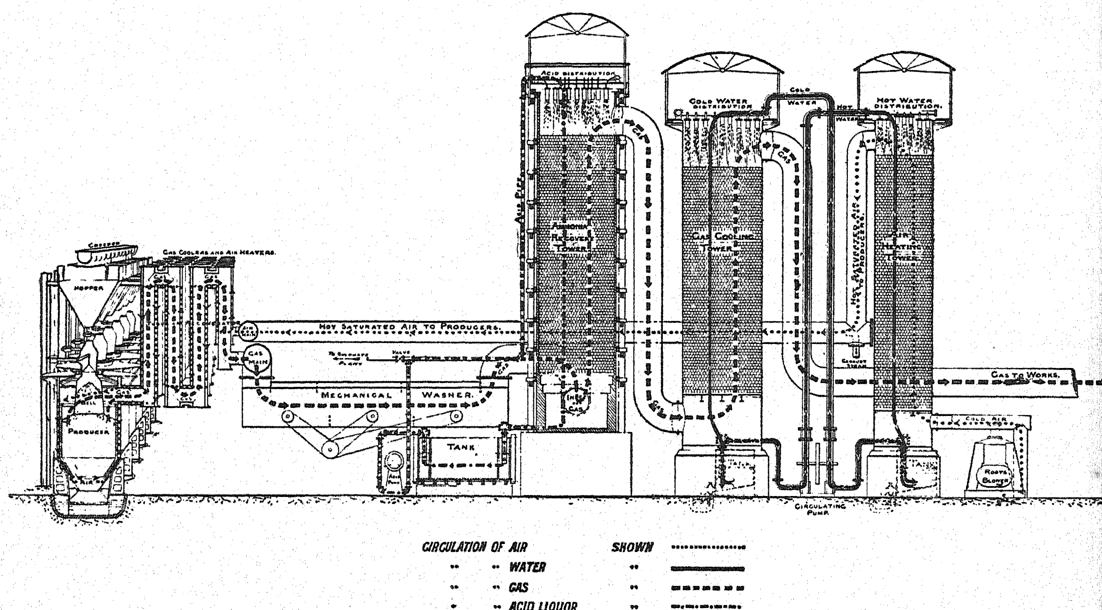


FIG. 227.—Diagram of Mond-gas plant with recovery of ammonia.

tower, where it meets a downward flow of hot water; the air becomes heated and saturated with water vapour, thus producing a mixture of air and steam: this mixture traverses a pipe leading to the tubular regenerator, which is a system of zigzag pipes arranged with a second system of pipes inside the first system. The steam and air passes in one direction along the annular space between the two sets of pipes, while hot gas from the producer passes in the opposite direction through the inside system of pipes; thus the mixture of air and steam receives the heat transmitted from the hot gas through central pipes, and is thus still further heated before it reaches the producer; finally, the air is again further heated by its passage through the annular

space surrounding the producer on its downward course to the fire-grate. The course of the hot gas is shown by heavy dotted lines, and it will be noticed that after the gas is cooled in the tubular regenerator it passes through a 'mechanical washer,' which is the name applied to a large rectangular iron chamber fitted with revolving dashers which rotate and fill the whole chamber with water spray. The partly cooled gas is here further cooled and washed, and, moreover, its remaining sensible heat is transformed into latent heat by the evaporation of some of the water. The gas, laden with its burden of steam, is then seen to traverse, from bottom to top, a large tower, called the acid tower, down which a stream of sulphate of ammonia liquor is always descending. This liquor contains some free sulphuric acid, and a strong chemical affinity causes the acid to take up the ammonia contained in the gas, converting it into sulphate of ammonia. To make the action continuous, some free acid is always being added and some sulphate of ammonia liquor removed from the plant for evaporation and the production of solid sulphate of ammonia for the market. The gas and steam next pass downwards to the inlet of the 'gas-cooling tower,' in ascending which it meets a stream of cold water, which serves the double purpose of cleaning and cooling the gas and condensing the steam it contains. By this process of condensation the steam gives up its latent heat; the water circulating through the tower thus becomes hot, and is pumped to the top of the air-heating tower, to commence a fresh cycle of operations. All the towers contain metalline tile fillings, so as to present a large surface to the gases, and the circulating water forms a means of regenerating the heat which is transferred from the gas to the air intended for the producer blast. The six producers shown in perspective on the left-hand side have large hoppers carried above them on frameworks which hold a considerable supply of coal, and which are filled by means of an elevator and creeper direct from railway wagons, so that the 120 tons of coal per day which this plant is capable of gasifying is all dealt with mechanically, and hand labour is reduced to the minimum possible." (*Producer-Gas*, H. A. Humphrey.)

Mr. W. Jackson, A.R.C.S., instructor in pottery to the Staffordshire County Council, has ably discussed the question of the use of producer-gas in firing earthenware potters' ovens. He explains that "The series of changes taking place in an oven during the combustion of the fuel are somewhat complicated. To fully understand them we must imagine we have an oven mouth in full heat and just charged with fuel. Air enters through the bars and over the fuel in some cases. That portion entering through the bars passes first through incandescent coke, and the oxygen of the air burns to carbon dioxide. It then rises through the upper layers of incandescent coke, and is reduced to carbon monoxide; at the same time the water vapour in the gases is decomposed, and yields carbon monoxide by combination of its oxygen with

carbon and free hydrogen. The gases now pass upwards at a high temperature through the fresh coal, which is thereby distilled, yielding crude illuminating gas containing hydrogen, methane, olefines, heavy hydrocarbons, and tar. All these are carried forward into the oven. Hence the gases entering the oven will be carbon monoxide, hydrogen, methane, olefines, heavy hydrocarbons, tar, and nitrogen, along with variable amounts of carbon dioxide, sulphuric oxide, etc. . . . . There is poured into the oven, at a high temperature, this mixture of combustible gases. The composition, of course, varies with the progress of the burning of each 'baiting,' and when the mouth is burning low the effect will be to produce little but a mixture of carbon monoxide, hydrogen, nitrogen, and carbon dioxide. Put in a few words, at an early stage of burning the fuel yields a mixture of producer-gas, illuminating gas, and tar; later, producer-gas only. The heat developed in the mouth finds its occupation in producing these gases, and not in firing the oven. Not a tithe of the heat required in the oven is generated in the mouth. The mouth is purely and simply a gas-producer. It is the combustion of this gas within the oven which generates the required heat. . . . .

"The gases from the mouth issue at a high temperature into the oven through the bags and the other flues. When entering the oven they meet currents of air drawn in by the draught. Combination takes place between the combustible portion of these gases and the oxygen of the air, and a high temperature is produced. Carbon monoxide burning in air gives a temperature of 1400° C. In a sufficient supply of air, carbon monoxide, hydrogen, and methane burn almost instantaneously, and a very large amount of heat is produced. Unless a large volume of other gases is present to take up this heat, there will be an intensely high local temperature produced, which would be detrimental to the wares and saggers. But the accompanying gases, nitrogen, hydrocarbons, tarry vapours from the mouth, and the excess of air which has been introduced, prevent this overheating, partly by being heated themselves, and partly by undergoing decomposition. This decomposition, which affects only the hydrocarbons and tars, results in the separation of free carbon as solid particles, and the formation of lighter compounds, which are in turn broken up in the same way until methane results, which then burns as such. In other words, pure coal has been transferred from the mouth to the interior of the oven by these operations. Eventually the carbon burns. The heat which fires the oven is thus produced inside the oven practically in contact with the saggers. . . . .

"Potters' ovens are thus practically gas-fired at the present time, but with a gas distinctly different from producer-gas as generally understood. Whether the same degree of success and economy will attend attempts to use producer-gas or Mond gas in our present ovens, or even in ovens of approximately the

same type, is doubtful. In these gases the most valuable constituent present in our oven gases, as now generated, is missing—in fact, very special precautions are taken to remove it; namely, the heavy compounds of hydrogen and carbon which we have seen play such an important part in our present practice. The rapidity with which combustion of producer-gas takes place is a great disadvantage. A short flame of excessively high temperature is produced, and intense local heating results. A comparison of the temperature in the combustion chamber at the bottom of a bench of gas retorts fired with producer-gas, and that in the top retort at a distance of some 7 feet only, will indicate very conclusively the effect of this rapid combustion. We have found a temperature difference of 600° C. between these two points distant only by an amount equal to one-third the height of an oven. The problem to be solved would be to obtain a uniform distribution of the heat produced by this combustion. By admitting small amounts of air at a number of points so as to allow a gradual burning of the gas, we would obtain a strong reducing atmosphere through the greater part of the oven, which would ruin glazes containing lead and many bodies. To introduce gas at a large number of places—and in ovens of the present dimensions (which are often some 20 feet in diameter and 20 feet high) it would necessitate introduction of gas, not only at various levels round the oven, but at various levels at varying points within the oven along with the necessary air-supplies—would lead to extremely complicated arrangements. To introduce an excess of gas would lead to reduction. All these means of meeting the problem would most likely fail. Either ovens would need to be much smaller, so as to enable the points of introduction of gas to be evenly distributed throughout them, or some means would need to be adopted for introducing the heavy hydrocarbons which the gas lacks.

"The difficulties to be overcome are very great. True, gas is used for firing clay-wares, but it will be observed that producer-gas has been applied only to the burning of refractory goods. At Glenboig, where are some of the oldest of gas-fired ovens, the ware fired is made from an exceedingly refractory clay. They are high-class fireclay goods. At Farnley producer-gas is used for refractory goods. At Charlottenburg it is used for hard-paste porcelain, again a very refractory ware. Whenever gas-firing is attempted for goods requiring medium temperatures, such as those of this district [Staffordshire], there has always been the trouble of local heating. . . . .

"The experience of the Americans with oil-firing, which is certainly more likely to give good results than producer-gas, shows that, to get a temperature of Cone 5 (=thermoscope bar 27) in the oven, Cone 25 (=bar 47) was brought down in the mouth; again the trouble of local heating. These facts indicate the difficulty to be expected in the adoption of gas-firing." (*Pottery Gazette*, June 1903, pp. 609–610.)

Before a Special Committee of the House of Lords, which sat on 7th May 1903, to consider a Bill for the incorporation of a company for supplying electricity and power-gas in Cheshire, Denbighshire, Flintshire, parts of Derbyshire, and Staffordshire, T. W. Twyford, Esq., of Cliff Vale Pottery, Hanley, gave important practical evidence as to the value and utility of the gas for use in pottery manufacture.

After entering briefly into statistics relating to the North Staffordshire district, he stated :—"The particular advantage to the potting industry of substituting gas-heating for coal would be the great saving in the prevention of loss. At present they could not rely upon the temperature of the ovens, and the consequence was they suffered great loss. . . . . The use of coal involves very great irregularity in the heat. He considered the loss sustained through this irregularity in heating to be quite 10 per cent., and by the application of gas-heating he expected to save. Then there would be the saving of the brickwork of the ovens, and they would save about five-sixths of the present cost of saggars used in firing pottery. . . . . He thought from what he could see, and without taking an exaggerated view of it, that on all these things they could save 20 to 25 per cent. independently of the fuel. . . . . The avoidance of smoke would increase the residential attractions of the district. . . . . Experiments had been made to his knowledge of using ordinary gas for gas ovens, but they had been a total failure. . . . . As to the application of this Mond gas, personally he had not tried it, but there were large firms who are engaged in exactly the same interest as he was engaged in—the making of very large pieces of pottery. They are using gas, and have plants of their own, and are using it most successfully for the purposes for which he wanted it. There is evidence that the gas has been practically tried. Mr. Twyford said that the primary object of introducing Mond gas to the potter was for the purpose of firing his ovens. He personally wanted it for firing his ovens and kilns." (*Pottery Gazette*, June 1903, p. 616.)

The importance of this matter of firing potters' ovens and kilns by means of gas has been officially recognized by the English China Manufacturers' Association, who held a meeting at Longton, on 25th April 1904, to hear a paper by Mr. G. C. Kent, town clerk of Longton, embodying the results of a series of very careful investigations into the subject both in this country and in the United States of America.

This paper, and the discussion it gave rise to, form a highly practical and interesting statement of the case; and as they are clearly worthy of a permanent place in the literature of ceramic art, permission for reprinting in this volume was solicited, both of the author of the paper—Mr. G. C. Kent—and of the editor of the *Staffordshire Sentinel*, and most courteously acceded.

The report, as it appeared in the *Staffordshire Sentinel*, 26th April 1904, slightly abridged, reads as follows:—

"GAS-FIRING OF OVENS.

"An important meeting of the English China Manufacturers' Association, to which manufacturers engaged in the earthenware branch of the industry were invited, was held at the Crown and Anchor Hotel, Longton, on Monday afternoon, at which Mr. G. C. Kent (town clerk of Longton) read a valuable and instructive paper—based on investigations made during his late visit to America—giving a description of the process, and a statement of the cost of firing potters' ovens with natural gas, together with a comparison of the cost of firing with ordinary coal-gas and with Mond gas. There was a good attendance of representative manufacturers, and in the absence of Mr. E. Asbury (president of the Association) Mr. E. Brain was voted to the chair.

"On rising to read his paper, Mr. Kent was very cordially received. He said:—It is with some hesitation and a considerable amount of diffidence that I come before you to-day in what is to me an entirely new rôle, and I would like first to thank you for the compliment you pay me by attending here to hear what I had to say on the interesting subject of firing potters' ovens by gas. The importance of the subject to us all, both individually and as it affects the district to which we belong, renders it unnecessary for me to make either excuse or apology. Before proceeding, however, I think it desirable I should make a few explanatory remarks, which I shall do as briefly as possible.

"You will remember that, upwards of a year ago, a Bill in Parliament was promoted by a syndicate of influential gentlemen to authorise, among other things, the manufacture and supply of power-gas for various purposes, over a very large area, which included this particular district. I went into the matter myself very fully at the time, and was instrumental in calling several meetings of representatives of local authorities, and subsequently joint meetings of those representatives and members of the Chamber of Commerce and Manufacturers' Associations, at some of which representatives of the syndicate were present, and gave an explanation of their proposals. The promoters obtained a considerable amount of support among the manufacturers and traders of the district, and such opposition as was presented by the local authorities—in the Potteries at anyrate—was not to the objects and scope of the Bill, but was for the purpose of obtaining amendments and clauses for the protection of their streets and undertakings, in the same way as they had been able to do on the introduction of electric tramways, etc. The necessary amendments were promised by the representatives of the promoters at the conferences, but the fact that it was necessary to take up a position of apparent opposition was proved by the fact that the suggested

amendments and clauses were not finally conceded by those in charge of the Bill until after it had passed the Lords' Committee, and, in its mutilated condition, finally passed the Commons' Committee. It was only by the loyalty of Mr. Twyford (the chairman of the promoters) to the promises referred to, and his insistence upon his friends and neighbours being properly protected, that specific amendments and something in the nature of the most-favoured-nation clauses were obtained. I only mention these facts to make quite clear and justify the position taken up by the local authorities, as the moment the conditions were agreed everybody welcomed the advent of the Act, and hoped great things from it. I had the privilege myself, not only of hearing all that was said on behalf of the promoters at the meetings referred to, but also the whole of the speeches and evidence, for and against, submitted to the Committees who sat upon the Bill, in both Houses, and the point that struck me most throughout was the entire absence of any definite statements or experiences as to the applicability of Mond gas for firing potters' ovens. It appeared to be taken for granted, and whatever questions were asked seemed to be treated by the experts representing the promoters in a light and airy fashion, and the practicability was accepted very much as a matter of course. It was stated at one of the conferences that the local gas engineers then present were prepared to have submitted some very interesting statements, but when this was mentioned an influential speaker said that any such statements would be taken with a grain of salt, and consequently the opportunity passed. I several times urged the importance of the possibility of firing a potter's oven with Mond gas, and I felt very strongly that the matter should not rest where it did. The subject interested me greatly, and I determined to follow it up. I first made inquiries into the system of gas-firing as carried on in the United States of America, and after conferring with my friend Mr. Thomas Taylor (of Taylor, Tunnicliff, & Co., Ltd., Hanley), who I knew took a considerable practical interest in the subject, we decided to take advantage of a visit we proposed to pay to America last autumn, and make a personal investigation of the process of firing potters' ovens there with natural gas. Our experiences were both interesting and astonishing, and we obtained a considerable amount of useful information on the subject. I very carefully tabulated the results of our inquiries from my own point of view, and on my return I placed them before competent authorities, for certain calculations to be made and conclusions verified. When these were complete they were all sent out to America for further verification, and I may say I was so surprised at some of the obvious conclusions, and so anxious that no incorrect statement should go forth through me, that the details have gone to and fro three times at least before I felt absolute confidence in making public the results of the inquiries and investigations—(hear, hear)—and my conclusions thereon, which I now venture to do with the fullest confidence as to

their accuracy. I would like at this point to express my sincere acknowledgments to Mr. Langford, the gas engineer of the Longton Corporation, for the willing assistance he has given me in the matter, and to Mr. Prince, the gas engineer of the Stoke Corporation, and Mr. Surtees, the gas engineer of the Fenton District Council, for checking and verifying the calculations and conclusions; and also to friends in East Liverpool who so readily gave every assistance and information in their power, including Mr. Elijah Mountford and Mr. Arthur Mountford, of the Homer Lauchlin Pottery, both formerly of this district, and well known to many here, and Mr. Herbert Goodwin of the C. C. Thompson Pottery, who formerly worked and resided in this town. I want you quite clearly, however, to understand that the facts and figures I propose to put before you do not for a moment profess to be those of a scientist or an expert, either from the gas or pottery point of view, but simply those of a friendly outsider and one whose only object is to serve the trade and interests of his native town and fellow-townsmen. (Hear, hear.) I ask you to pardon this digression, and will now proceed with the formal matter I have to lay before you; and if there is any point upon which I do not make myself quite clear, I shall be glad to give you any further information and explanation you may desire. (Hear, hear.)

"Proceeding, Mr. Kent said:—Although perhaps hardly necessary in the home of English pottery manufacture, it may be mentioned at the outset that the common method of firing potters' ovens and kilns is with ordinary coal. In England, at anyrate, firing by any other means has never been carried out successfully on a commercial scale, or otherwise than experimentally, although it has long been felt that the process was a wasteful and extravagant one in many respects, and by no means uniformly successful in results. On the introduction of potting as an industry in the United States of America, the same method of firing was adopted, and is still carried on at Trenton and other places at present outside the limits of supply of natural gas; and it appears to be the fact that in America, as in Great Britain, very little progress has been made in the direction of firing with manufactured gas. On the other hand, East Liverpool, in the State of Ohio, which has now become one of the largest seats of the potting trade in the States, is within the limits of supply of natural gas, and has not failed to take advantage of the situation. The town occupies a magnificent position on both sides of the Ohio River, with well-wooded heights beyond on either side. The river is very wide and navigable, although suffering from great fluctuations as to depth of water according to the season. There is excellent railway accommodation on a main line running direct from the important city of Pittsburg, which is about fifty miles distant, and East Liverpool might in time have degenerated into the well-known smoky and overcast appearance of the district around Pittsburg but for the introduction of natural gas. There are no coalfields

in the neighbourhood of East Liverpool, so the cost of coal suitable for potters' purposes is considerable, although as far as could be gathered—notwithstanding the fact that the freight cost about as much as the coal at the mine —it did not appear to be more than the price paid for potters' coal in the Staffordshire Potteries. The high cost of fuel led to experiments in firing the ovens and kilns with natural gas, with the result that its use has now been adopted at most of the pottery works for firing purposes generally, as well as for driving gas-engines and for heating ordinary steam-boilers. The gas-fields are situated about forty miles from East Liverpool, and are owned and worked by companies who collect the gas and convey it across country for long distances, in different directions, in pipes of various sizes, the largest size supplying East Liverpool being 16 inches in diameter. These comparatively small pipes appeared to be preferred to larger ones, as the leakage is stated to be less, and the pipes can be multiplied according to the demand. To anyone who has been accustomed to the appearance of other pottery-manufacturing districts, the most noticeable feature on approaching the district where the gas-fired pottery works are situated is the clear sky and the absence of smoke and fumes; and it may be stated at once, and in the most positive terms, that careful investigation failed to detect the slightest trace of fumes or of any nuisance or annoyance having been caused by the use of natural gas either inside or outside the place where it is used. There are numerous works using gas in the manufacture of pottery, but the conditions and methods appear to be very much the same all round, so that a description of its application and use at one of the largest and most modern places may be taken as descriptive of the process generally. The manufactory in question is constructed in three blocks of different sizes, and the ovens in each block are placed in a straight line, and roofed over with the workshops and warehouses on both sides. There are altogether thirty-two ovens, most of which are in constant use, and on the occasion of the visit referred to in this description eleven of them were in process of firing with natural gas in different stages. It was stated that most, if not all, of the ovens had been constructed for firing with coal before the mouths were altered for firing with gas, and had been so fired; and that on the introduction of the gas-firing no alterations were required in the construction or internal arrangements of the ovens, the only alterations made at the time being in the firing-mouths and connecting-flues, and what alterations have been made since have been the results of experience or for experimental purposes; and if from any cause it should become necessary to return to coal-firing either permanently or temporarily—as has happened—the reconversion can be carried out at small cost and with very little inconvenience. How important this point is may be judged from the fact that in the English newspapers of the 4th April 1904 it was reported, in a telegram from the

State of Ohio, that twenty towns had been deprived, by floods, of natural gas, and several cities had no power for their waterworks, for lighting purposes, or for their electrical tramways, and that many factories had been closed. This shows the extent to which natural gas is applied for fuel and power purposes instead of coal. To return to the ovens, the usual size is 20 feet outside and 16 feet 6 inches inside diameter, with ten firing-mouths to each. The placing and drawing are carried out in exactly the same manner in all respects as in firing with coal, except that with gas the conditions are better and cleaner, as there is an entire absence of coal-dust and ashes, as well as of the labour of shovelling, wheeling, and otherwise dealing with coal and ashes. The gas company's main is laid along the street, and from the main there is an 8-inch pipe to one end of the range of ovens where a regulating and reducing valve is fixed. From this valve a 6-inch pipe is carried underground along the range of ovens from end to end, and at each oven there is a 3-inch branch which runs underground right round the oven, and is continuous throughout. There is a $\frac{1}{4}$-inch branch at the right side of each mouth rising through the floor, with a regulating open and shut valve worked from the top; and from the left side of the upright pipe there is a straight length of $1\frac{1}{4}$-inch pipe running right across the oven-mouth about 10 inches from the ground. Out of this straight length are three delivery pipes fixed at right angles, the first and second being $1\frac{1}{4}$ inch and the third 1 inch in diameter, each with an open nozzle projecting for some distance into the mouth through an opening formed by leaving out half a brick. On each nozzle-length there is a bunsen-burner with a revolving hit-and-miss air-regulator, and under each nozzle-length at the floor-level another half brick is left out for an additional air-inlet. The ashhole or under portion of the oven-mouth is entirely bricked up with the exception of the six half-brick air-spaces before mentioned, and above there is the ordinary firing-mouth with cast-iron door and frame, which are left intact, but are now only used for the purpose of observation; and there is a trial-hole over each mouth a few courses above the shoulder. The outer casing in the mouth is of 9-inch brickwork with an inner lining of single fire-bricks through which the gas nozzles extend, then there is a space for combustion and a firebrick backing with sloping shoulder at the top over which the flames travel. Behind this there is a packing of roll-bits or other similar material among which the flames are diffused; and as this material becomes incandescent, the intense heat passes on in a body to its work through the flues and oven generally. The combustion is perfect and equal throughout, and under absolute control at all points, and there is little or nothing to get out of order. The gas pressure in the main is very considerable, being from 10 lbs. to 15 lbs. per square inch; but this is reduced at the valve before reaching the range of ovens to a pressure of 11 ozs. in the mercury gauge, and it is further reduced at the oven itself to 6 ozs. or 8 ozs.

Each oven is supplied with a suitable pressure-gauge, which is fixed in a prominent and convenient position, so that the supply of gas as well as the heat generally can at any time be regulated with the utmost nicety as required. As the oven gets hot the consumption of gas decreases and is regulated accordingly. No special skill is needed, and an ordinary workman soon becomes accustomed to the process and competent to carry out the work. The calorific value of the natural gas is very high, being approximately 1000 British thermal units. The consumption of gas per oven was stated to be from 280,000 to 300,000 cubic feet for a biscuit oven, which takes about fifty-six hours to fire up; and about 20,000 feet less for a glost oven, which takes about thirty-six hours to fire up. The price charged for the gas is 4d. or 5d. per 1000 feet, according to the total consumption of the works, but the usual price may be taken as 5d. This works out roughly at £6, 5s. per oven, which was stated to be pretty near the same cost as firing with coal. Apart from the gas service, the cost of converting an oven from coal to gas firing is limited to about one thousand firebricks and the necessary labour. Enamel kilns are fired in the same way as ovens, and are quite as easily and cheaply converted from and to coal-firing. At the works mentioned there are upwards of twenty kilns, mostly four-mouthed, and arranged in twos from end to end. At another manufactory the experiment has been tried of constructing an enamel kiln over the top of an oven, and firing it with the waste heat from the oven, and this is reported to have proved a success. In the ordinary kiln the gas is applied in the same way as to the ovens, except that there are only two nozzles to each mouth instead of three. The gas is also used in these works for generating steam for heating purposes and for driving gas-engines. The type of engine used is 35 h.p. nominal, with electric ignition and battery of cells. The consumption is 2000 feet, or a cost of 10d. per day for gas. At other places the gas is used for generating steam for motive power, and the methods of use and application are as simple as those already described. The fire-holes are filled in right up to the boiler with firebricks built loose with wide spaces. The bricks break up and diffuse the flames and retain the heat, and, like the roll-bits in the ovens, form a sort of regenerative furnace. The fronts of the fire-holes are built up, and the gas is supplied through three nozzles in the same way as in oven-firing, except that there are a number of small perforations in a cap at the delivery end of the nozzle instead of one large hole. There is an entire absence of deposit in the flues, and, of course, neither smoke, dust, nor ashes. The results were stated to be eminently satisfactory, and the conversion from and to coal-firing can be effected simply and at nominal cost. It is of course difficult to make anything like an exact comparison between the process and cost of firing potters' ovens with natural gas as before described, and of firing similar ovens as now carried on in the Staffordshire Potteries with coal, or as it might be possible to fire them either

with ordinary coal-gas, or with Mond gas or other producer-gas. It may, however, be taken for granted that, apart from the question of cost, which will be dealt with later on, the process of firing potters' ovens with gas presents many decided and important advantages over the process of firing with coal, such, for instance, as the ease and simplicity of starting the fire, the saving of the cost of drawing the coal to the ovens and carrying or wheeling to the mouths, the entire absence of coal-dust, dirt, ashes, and clinkers, the doing away with damage to the mouths by punching, the absence of fire-bars, the saving of moving and carting away ashes, the very considerable increase in the life of the saggars and of the ovens themselves, the general cleanliness, and last, but not least, the better and more uniform character of the fired ware, with the consequent reduction in the quantity of seconds and other inferior goods, so that even if it should cost considerably more to fire with gas than with coal there might still remain a very decided advantage from the use of gas. Careful inquiries and investigations have therefore been made, first as to the practicability (as to which, however, there could be little doubt), and secondly, as to the cost, as near as could be ascertained, of firing potters' ovens both with ordinary coal-gas as now manufactured in the Potteries, and also with Mond gas as proposed to be introduced in the district. It is believed that the practicability may be accepted, but the cost at present, at anyrate, can only be estimated by comparison. As far as coal-gas is concerned, a small experimental oven has been erected and fired with perfectly satisfactory results, although no attempt was made to check the cost. The ware fired was satisfactory and was passed into use. No experiment or demonstration appears to have been made at present with Mond gas, but there seems to be no reason to doubt its applicability for pottery purposes under certain conditions.

With regard to the question of cost, the calorific value and the pressure of the gas used must be taken into consideration. In these respects it is evident that the natural gas as supplied at East Liverpool is particularly well adapted for firing and heating purposes generally, as it possesses such high calorific value and is delivered at such high pressure in comparison with illuminating or other manufactured gas. The question of pressure can doubtless be dealt with, and, except so far as it affects the question of cost, is not taken into account in the following calculations. The calorific value of natural gas is, as before stated, equal to 1000 British thermal units, whereas the value of ordinary coal-gas as supplied in the Potteries does not exceed 600 units; and as it is admitted by the experts supporting the introduction of Mond gas that its value does not exceed one-fourth that of illuminating gas, the calorific value of Mond gas may reasonably be taken as not exceeding 150 British thermal units. That being so, it follows that the quantity of either coal-gas or Mond gas required for any given purpose must be very greatly in excess of

the quantity of natural gas required to obtain the same results. On these lines it is a very simple calculation that if it takes 300,000 cubic feet of natural gas to fire a biscuit oven, it would take 500,000 feet of ordinary coal-gas and 2,000,000 feet of Mond gas to do the same work. Assuming that coal-gas could be produced and supplied at as low a price as 1s. 6d. a thousand feet, and Mond gas at 3d. a thousand feet, as has been suggested, the cost of firing potters' ovens even at these low prices would work out in the case of coal-gas at £37, 10s., and in the case of Mond gas at £25 per oven, as against £6, 5s. with natural gas, and as against the cost of coal for the time being, whatever it may be. The price of potters' coal in the Potteries is probably about the same as at East Liverpool, and while it is quite clear that, with the cost of firing an oven being about the same for gas as for coal, the advantages are altogether on the side of gas, it appears, unfortunately, only too certain that with all those advantages, great as they undoubtedly are, the use of gas would be quite out of the question with the cost six times or even four times the price of coal. Dealing first, therefore, with the question of ordinary coal-gas, it may be stated that it is extremely doubtful if it could be manufactured and supplied in the Potteries under existing conditions at as low a price as 1s. 6d. a thousand feet, for the reason that the undertakings for the manufacture and supply of illuminating gas would not be able with their present plant and mains to produce and distribute the gas in the large quantities required for a general supply. The manufacture and supply would have to be carried on either as additions to or separately from the existing undertakings, with the consequent large additions to the capital of such undertakings, which, as they are mostly in the hands of local authorities, presents a feature of very considerable difficulty at the present time. It is no doubt possible that in the course of time, and with experience in the manufacture and use of gas for firing purposes, improvements and economies might be effected both in the methods of manufacture and in the processes of application, by which the cost of production as well as the consumption would be very materially reduced; but for the present, at anyrate, it would appear that, however desirable, the possibility of firing potters' ovens with ordinary coal-gas must for the before-mentioned reasons, and mainly because of its excessive cost as compared with coal, be dismissed altogether for practical purposes. Where, however, cost is not a consideration, it would be practicable, and possibly beneficial, to erect small ovens and kilns and to fire them with ordinary coal-gas in cases of emergency or for experimental purposes; but a matter of that kind hardly comes within the scope of this comparative statement. Now, with regard to Mond gas and producer-gas generally, it is an undoubted fact that it can be manufactured in very large quantities and at a very low cost, but it is doubtful if it could be supplied at a penny per thousand feet; and taking into consideration its very low calorific value, it would have to be supplied at less than this price to enable it to

compete with coal in the firing of potters' ovens. Assuming, however, that this can be done, there is the difficulty of transporting and distributing the gas from the place of production to the various places of consumption in the enormous quantities that would be required. In this connection it cannot too carefully be borne in mind that nearly all the ovens in the district are fired at one and the same time, so that while on certain days of the week the consumption would be very small, on other consecutive days the consumption would be so great that the gas could not possibly be produced from central stations as required, and therefore immense storage capacity would be necessary. What the quantity required during the period of firing the ovens would be, and the difficulty in the way of storage, may be roughly gathered by multiplying the consumption per oven by the number of ovens firing at any particular time, and then bearing in mind that there are very few gas-holders in the district at the present time which have a holding capacity of half a million cubic feet. It would, no doubt, be possible to reduce the bulk considerably by compression, but in view of the risk, and with the experience of the high percentage of loss by leakage during storage and distribution in the case of ordinary coal-gas, which is supplied at a very low pressure, it appears that there is a limit beyond which it is neither wise nor safe to go. Considering all those points, it is difficult to see how Mond or other producer gas can be manufactured and stored at, or distributed from, large central stations, as is done with illuminating gas; and the conclusions one is irresistibly driven to are that, if such gas is to be made available for potters' purposes, it must first be produced at an exceedingly low price, and, next, must be manufactured at or near the spot where it is required to be consumed. These two points appear to be antagonistic, but the problem ought not to be incapable of solution by any means. There is certainly a very wide and interesting field for investigation and experiment before the practical commercial application of manufactured gas in any form for potters' purposes can be solved; and surely, in view of the importance of the subject, and of the monopoly recently granted by Parliament for the supply of Mond gas in the district, it is not too much to ask and hope that such investigations and experiment will be at once entered upon and proceeded with on a practical basis, and it may be confidently predicted that with the developments of modern science combined with experience the solution will be speedily arrived at. The benefits to be derived both by manufacturers and workers by the transition from coal to gas firing would unquestionably be enormous; the gain to the health, comfort, and welfare of the people generally would be incalculable; while the aspect of the whole district would be entirely changed, and the atmosphere of the Potteries would be removed from the region of satire to that of very pleasant reality. In conclusion, the general deductions to be drawn from the foregoing description and comparative statements, and the

investigations which have been made in preparing the same, may be briefly summed up as follows:—

"1. The practicability of firing potters' ovens with gas has been thoroughly and satisfactorily demonstrated.

"2. The advantages of the process are many and beyond question.

"3. That the existing ovens and kilns, etc., can be converted from coal to gas firing without reconstruction and at small cost.

"4. That natural gas, by reason of its high calorific value and low cost, is more than able to compete with coal for potters' purposes.

"5. That ordinary coal-gas or illuminating gas, by reason of its lower calorific value and high cost, is not under present conditions able to compete with coal, and its use for the purposes is impracticable.

"6. That Mond gas, by reason of its very low calorific value and the enormous quantities required in its normal condition, will be unable to compete with coal unless it can be supplied at less than a penny a thousand feet, or it can be produced at very little beyond that price on or near the spot where it is required to be used.

"7. That it is essential and due to the pottery trade that investigations should be made and experiments carried out without delay in order to ascertain and demonstrate the possibility of firing potters' ovens with Mond gas, and of supplying it at such a price as will enable it to compete with coal. The question of transporting the gas in large quantities must also be considered, and in the same connection attention must be given to the possibility of reducing the bulk, and at the same time materially increasing the calorific value of the gas. Any such experiments and demonstrations should be made and carried out on a practical working basis (and not a mere theoretical one), and under reliable supervision.

"If and when the difficulties now pointed out can be surmounted, ... the end, which everyone will admit to be so eminently desirable, will be within measurable distance. It is with the hope and in the confident belief that in the near future these difficulties both can and will be surmounted, and in no sense in a hostile or critical spirit, that this description and comparative statement have been prepared; and if the result will be to hasten and help on in the slightest degree this desirable consummation, the writer will feel amply rewarded for the trouble he has taken in this interesting and important matter. (Applause.)

"At the conclusion of his paper Mr. Kent handed round a number of photographs illustrating the construction of the ovens in which natural gas was used.

"THE DISCUSSION.

"Questions and comments were then invited, and Mr. James Aynsley asked if Mr. Kent had given any consideration to the cost of water-gas, and how it compared with coal or other produced gas.

"Mr. Kent: I have asked the question, and it comes to somewhere between the two. At present it is quite impracticable to use water-gas on a large scale for this particular purpose. There are legislative difficulties in the way of doing this at present; moreover, water-gas would have to be used in conjunction with some other gas.

"Mr. James Aynsley said that from what he had seen of the water-gas plant the cost to put it down was comparatively inexpensive. Beside, the calorific heat was much more intense than coal-gas.

"Mr. Kent agreed, and in reply to another question he said the price of 5d. a thousand for natural gas, which he had quoted, was the maximum sum that was paid.

"LIFE AND REPAIRS OF OVENS.

"Mr. S. L. Plant said they had had evidence that Mr. Kent had taken infinite pains in preparing his paper. He (Mr. Plant) wondered if Mr. Kent had ascertained on the spot what would be the natural life of an oven fired by natural gas.

"Mr. Kent said the question was asked at several places, but no specific answer was obtained. They were, however, told the life was many times that of ovens fired by coal.

"Mr. Plant: What was the average cost per year for repairs?

"Mr. F. H. Heath (who had also been on a visit to East Liverpool) answered this question. He said he spent some time about the ovens there, and realised it was impracticable to fire ovens by coal-gas under present conditions, because of the higher calorific power of the natural gas, and the fact that gas was there supplied under a pressure (ranging from several pounds and regulated by the fireman down to several ounces) which could not be got from the English lighting mains. So far as repairs of ovens were concerned, he asked the question at several factories, and in one case they said it had not cost a penny that year nor the year before. The fireman occasionally put in a new brick, and from the look of the ovens it would appear there was very little wear and tear. The life of the saggars was also—well, they would like to get Longton saggars to last as long. (Laughter.)

"Mr. Heath said that he did not find at East Liverpool an oven higher in the shoulder than 15 feet.

"MR. TAYLOR'S OBSERVATIONS.

"Mr. Taylor, on being asked by the chairman to express his views as Mr. Kent's travelling companion, said he did not think he had very much to add to the paper that had just been read, although there might be a few things in which he as a practical potter would differ from Mr. Kent. The conclusion he had arrived at himself was that, if he was going to build an oven to experiment with, he should never go in for Mond gas. He would first go in for the coal-gas supplied at present in Hanley. Mr. Taylor said he did not think Mr. Kent's figures were absolutely reliable. He had obtained a couple of ordinary gas kilns and worked them for a couple of months most successfully with coal-gas as supplied in Hanley. He had fired a small enamel kiln over and over again at a cost of 15d. for gas. Mr. Taylor gave an instance that he had received an urgent order for a few hundred articles which were required within a given time. There was no possibility of getting them through the kiln in the ordinary way, and he now produced some specimens of the ware fired in the way he had referred to. Mr. Taylor proceeded to say that it was not altogether a matter of the calorific value of coal-gas supplied in the Potteries, but what was required was greater body in gas, and thorough diffusion in the oven and a proper admixture with air. He had offered to fire ovens on his works if the gas company would only bring the gas to his works, and he was sure he could do it at a cost not much greater than coal. By the use of natural gas the American potters saved a good deal of wear and tear to ovens and saggars. The ovens in East Liverpool were practically built in the saggar-house, and that was an enormous saving and a great economy. The samples which he had presented had been fired at a cost of 3s. 9d. in a small kiln. He believed that whatever the extra cost of gas as against coal happened to be, they would not certainly lose by the use of gas, but they would save a great deal and do away with dirt and smoke. He trusted that, before long, experiments on a careful scale might be carried out which would enable them to ascertain exactly the comparative cost of firing by coal-gas and by coal and Mond gas

"Mr. Harold Plant said he had a little gas kiln he had used, and with this, by the use of ordinary gas, he had produced a piece of transparent ware in three-quarters of an hour, though the ware was blistered.

"Mr. Kent mentioned that the pressures he had quoted were not given during the visit, but he had obtained them since from experts—from the authorities of the Natural Gas Company, East Liverpool.

"Mr. T. Cone was asked to give his experiences, but said that while he had fired ovens on the Continent for some years, that was with raw coal, and he had had little experience with gas.

"VOTES OF THANKS.

"Mr. R. Jamieson, in moving a vote of thanks to Mr. Kent for his paper, expressed the gratitude of the manufacturers to Mr. Kent and to Mr. Taylor, who, he said, had started a subject which he hoped would not be allowed to drop. (Hear, hear.) Manufacturers must go on with the matter; something must be done to preserve the trade to the country. If other people were firing by gas, and doing it to advantage, Longton manufacturers must do it. (Hear, hear.) No doubt the investigations that had been made, and the experiments that would be made, would arouse such a considerable interest in the question of firing that it would lead to greater economy. By having a paper read to them by the town clerk they were more exceptionally favoured than if a manufacturer had brought the matter before them. (Hear, hear.) Though manufacturers' pockets were greatly affected by the matter, the outside public must not lose sight of the fact that the town of Longton was equally affected, and that every shopkeeper, and every single person who supplied the industry with materials, was as greatly affected as manufacturers. Mr. Jamieson said that Mr. Kent had been repeatedly solicited to make public his observations—more particularly by the gas-world journals—but he had resisted their blandishments, considering his first duty was to his own town. (Hear, hear.) For this and for his excellent paper Mr. Kent deserved their sincere thanks.

"OFFER BY MR. J. G. AYNSLEY.

"Mr. J. G. Aynsley, in seconding, said that he hoped with Mr. Taylor that the figures given by Mr. Kent were rather overdrawn. Proceeding, he said that if the Longton Corporation would allow any trial of gas to be made, he should be perfectly prepared to head a subscription list with £20 towards the cost of a kiln. If the Corporation would not undertake it themselves, he would give the same money towards the cost of the laying of the mains and arranging for the experiment to be made at any factory. (Hear, hear.)

"Mr. S. L. Plant, speaking in support, suggested that something useful might result if Mr. Kent and Mr. Taylor would meet a committee of three or four members of the association and give them their opinion as to whether we could produce china as well glazed as could be produced in America by gas-firing.

"The chairman also spoke in support of the resolution, saying he thought it was exceedingly good of Mr. Kent to spare so much time, and he thought they were very deeply indebted both to Mr. Kent and Mr. Taylor.

"The resolution was then carried amid applause.

"Mr. Jas. Aynsley said that on behalf of Messrs. Bridgwood he would be prepared to contribute £5 to the fund suggested by his brother.

"MR. KENT'S REPLY.

"Mr. Kent, in returning thanks, said that when he came back from America he was very strongly impressed with the idea not only of doing a good turn to the trade, but a good turn to that institution in which they were all pecuniarily interested, viz., the Longton gasworks. And his first business when he came back was to put it to their gas engineer as to whether it was possible to utilise the gasworks for providing a supply of gas from their works for firing potters' ovens. He then put the matter before the Gas Committee, and it met with the most sympathetic reception, and the question was referred to be gone into further, and draw up a report. If that report had been in the shape of a recommendation to the Gas Committee to spend some money in investigations and experiments, they would be only too willing and ready to have gone to whatever expenses might have been necessary for the purpose. But they went further into the matter, and came to the conclusion that the existing works and mains could not possibly cope with the quantity required for a general supply. The Committee were quite prepared to go into the matter, and the gas engineer was most enthusiastic. The Gas Committee found that it was impossible with the present gasworks and mains to give such a supply as would be practicable for potting purposes. The mains were only designed for the supply of gas for illuminating purposes and for use on gas-engines, and a tremendous additional outlay would be required to supply the gas to potters. The subject was surrounded by practical difficulties, but he was one of those who believed that the difficulties were not insurmountable either in regard to the use of coal-gas or Mond gas. Under present conditions he thought it was impossible to utilise Mond gas for potters' ovens if it was distributed from central stations. Where there were half a dozen manufacturers together there would be practically no difficulty in putting a plant on the spot which would serve a group, but he could not imagine how the Mond gas could be diffused through the whole of the towns. The Mond Gas Company owed it to the manufacturers to proceed with a practical demonstration at the earliest moment, and he thought they should be prepared not to manufacture the gas at central stations, but at a number of stations in the towns. (Hear, hear.) Mr. Kent thought that they ought to extend some assistance to the Gas Committee of the Longton Corporation, so that they would have two strings to their bow. The Gas Committee were quite prepared to act with the manufacturers in the matter of experiments, and he had not much doubt that for some purposes connected with the trade there was a very useful and wide field for the manufacture of gas.

"Mr. Taylor also acknowledged the vote of thanks, and urged that they should ascertain whether they could fire ovens with gas; the means of getting it would be a secondary consideration." (*Staff. Sentinel*, 26.4.04.)

The foregoing paper by Mr. G. C. Kent elicited the following reply from Mr. H. A. Humphrey, M.I.C.E., M.I.M.E., etc., which appeared in the *Staffordshire Sentinel* of 5th May 1904, and should be read as a context, with the object of arriving at a correct appreciation of the problem:—

"GAS-FIRING OF POTTERY OVENS.

"REPLY TO MR. G. C. KENT.

"(To the Editor of the *Staffordshire Sentinel.*)

"SIR,—My attention has been called to Mr. G. C. Kent's paper read before a meeting of the China Manufacturers' Association, held at the Crown and Anchor Hotel, Longton, and fully reported in your issue of the 26th April.

"Mr. Kent is so frank and honest in stating at the outset that the facts and figures he puts forward are not for a moment to be considered as those of a scientist or an expert, that one can only admire his daring in lecturing on a scientific subject. Mr. Kent's effort must be recognised as a kindly endeavour to help his fellow-townsmen, and the fact that he has gone widely astray need not detract from the praise and credit which such efforts merit. We have often heard of a mare's nest, but I never before had such an excellent example of a person finding a mare's egg and wrapping it carefully in wadding and sending it three times to America to get the species correctly verified and labelled, then exposing it to the admiring gaze of a number of eminent gentlemen, until at last he 'felt absolute confidence' in making the public acquainted with the results of his find.

"Mr. Kent is evidently a careful observer, and the descriptive portion of his paper, describing his visit to ovens fired by gas in various parts of America, is excellent, and will, I am sure, be much appreciated; but he goes on to perform a simple rule-of-three sum in arithmetic, and gives a few figures, occupying only a few lines of the four-column article, upon which he bases a series of deductions. He says that the calorific value of natural gas being 1000 B.T.U. per cubic foot, and the calorific value of Mond gas being 150, then, if it takes 300,000 cubic feet of natural gas to fire a biscuit oven, it would take 2,000,000 cubic feet of Mond gas to do the same work. It all looks so beautifully simple that one does not wonder that the various local experts who have examined the figures, should accept them as correct without apparently taking any trouble to find out how the Mond gas is to be applied, and in what important way the application differed from the use of natural gas.

"When Mr. Kent took so much pains in going to America (fortunately not alone for the purpose of his paper), he might surely have taken the much smaller amount of trouble in inquiring from the Power Gas Corporation, or those responsible for the introduction of the North-Western Electric and

Power Gas Bill, and ascertaining some particulars as to how the Mond gas was to be applied. He would have learnt at once that the basis of truly economic working is to be found in a system of regeneration, the adoption of which renders his statement of gas consumed and costs quite valueless and inapplicable to the case. Let us for a minute see how entirely wrong the rule-of-three sum applied to calories may work out in practice.

"In Messrs. Head and Pouff's paper published in the *Iron and Steel Institute Journal* of 1889 (which is the case I take simply because I have the figures in front of me at the moment), a bar-iron furnace, which in the ordinary course of firing with coal took 22½ cwts., when fired by gas applied to regenerative furnaces took only 5½ cwts. to do the same amount of work. Taking the calories in a ton of coal as 100 per cent., and the calories in the gas as approximately 80 per cent. of the coal from which it is derived, then Mr. Kent's rule-of-three sum would run as follows:—

Coal per ton of bar-iron produced, ... 22½ cwts.
Coal gasified to produce the same amount of calories in gas, ... 26 cwts. nearly

instead of the 5½ cwts. actually employed. This shows the gross error of the rule-of-three principle applied simply to the calories in the gas, because the principle of regeneration has been entirely overlooked or ignored by Mr. Kent.

"In America the natural gas is burnt in the ovens, and the products of combustion are allowed to escape at a very high temperature, and about eight-tenths of the heat is entirely wasted. When Mond gas is applied for firing pottery ovens the heat will be regenerated, and passed back to the furnace so as to go round and round in cycles; and the degree of economy is only limited by the amount of care taken to transfer the heat from the outgoing products to the incoming gas and air, and the amount of protection against external radiation. If Mond gas were to be used in exactly the same way as natural gas is used, the figures given by the author of the paper read at Longton would be correct; but as it is not to be so used they are in no sense applicable, and all the deductions based upon them are entirely without value.

"Evidently Mr. Kent has a lurking notion that, after all, he may be entirely wrong in his idea, because, although he has apparently proved to his own satisfaction that firing by Mond gas is impossible, he goes on to suggest the advisability of trying the experiment on a commercial scale. He even suggests, further, that lighting gas should be tried for firing ovens, apparently in ignorance of the fact that the calories in the amount of lighting gas obtained from one ton of coal is less than one-third of the amount of calories in Mond gas obtained from one ton of coal; so that, even neglecting the great saving due to the recovery of the sulphate of ammonia with Mond gas, lighting gas has absolutely no chance of competing with Mond gas for the purpose

indicated, particularly so at the price stated to be the lowest at which lighting gas can be produced.

"Mr. Kent is evidently thoroughly good-hearted, and would act the philanthropist, and put himself to no little trouble in his aim to serve the public, and I trust I have in no way offended him in my criticism of his paper, the reading of which has afforded me some instruction and some amusement.

"Mond gas has been successfully applied to so many industrial purposes with so much success that we have a right to our faith in its successful application for firing pottery ovens. When the actual experiment suggested by Mr. Kent comes to be carried out, I feel sure we may venture to find an interested and keen supporter in Mr. Kent, who will be ready to help us in every possible way.—Yours, etc.,

"H. A. HUMPHREY, M.I.C.E., M.I.M.E., M.I.E.E."

Some adverse comments upon the practical utility of producer-gas for brick-burning appear in the *British Clayworker*, October 1903, reprinted from the *Clayworker*, U.S., a portion of which deserves careful perusal:—"It was but a few years ago that the country was being flooded with literature bearing upon the economy and utility of using producer-gas for fuel. . . . . The infallible success of producer-gas fuel was pictured to us in such glowing colours that we concluded to try the experiment thoroughly, regardless of expense. The first question was—Which is the best gas-producer? Upon personal investigation, and on the strength of first-class testimonials, we concluded to adopt the X.Y.Z. gas-producer. Now, in order to be sure that the gas-supply would at all times be sufficient, we erected one of the largest gas-producers of its type. Next came the kiln question. . . . . It was determined to erect a separate down-draught kiln . . . . upon lines which twenty-five years' experience in the brick business gave our superintendent. All the flues, air and gas inlets, and valves for same, were planned and constructed with the greatest accuracy and care. . . . . After all preparations had been carried out, the first kiln was filled and burned, but the result was not a complete success. The colour was fair, but the bricks were too soft. Of course, all kinds of excuses were made and suggestions offered, and we tried it again. The second time the bricks were burned too hard on the top and too soft on the bottom. . . . . We went at it again, but the several burns were not altogether successful. . . . . The blame was put on the coal, and naturally we began experimenting with different kinds of coal, its selection being governed by its constituents of volatile hydrocarbons. Yet the results obtained in burning were not entirely satisfactory. It was discovered that quite a volume of the distilled hydrocarbons were condensed in the tunnels as tar, and its effectiveness as fuel was lost, so much so that the cost was enhanced over the cost had the fuel been used directly on the kiln grates. We eventually got tired of the

continuous experimenting, and dismantled kilns and gas-producer." (*British Clayworker*, October 1903, p. 259.)

To the foregoing a reply appeared in the November 1903 issue of *British Clayworker*, p. 277, from which the following is an excerpt:—"Mr. James Dunnachie, managing director of the Glenboig Union Fireclay Company, Limited, writes us as follows:—'. . . . Had your clayworker erected a "Dunnachie kiln" as designed by the patentee, instead of "a kiln of the Dunnachie type," he would not have encountered one of the difficulties which troubled him, but he would have found instead all the economy and utility he had hoped for when he started his experiments. How often do we hear of men puzzling their brains with problems that have already been satisfactorily solved, simply because they have not made sufficient inquiry, or because they like to do everything in their own way! Your American clayworker failed to reach the necessary temperature for proper burning, and, in addition, the bricks were too hard on the top of the kiln and too soft on the bottom, a result clearly showing imperfect diffusion, probably due to unskilful setting. . . . .

"'The only problem for the brick-burner is the even distribution of the heat. . . . . This has been accomplished to perfection in the "Dunnachie kiln" as operated at Glenboig, where there are now fifty kilns constantly at work, giving better results as regards quality of goods, and greater economy as compared with the ordinary systems of firing. The regulation of the air-supply also seems to have given your clayworker much trouble, and he concludes that, because of the variations in quality of producer-gas, it cannot be regulated to give a flame with continuous oxidizing effect. The producer used by him must have been troublesome in this respect, requiring constant watching after charging, and again after the lighter hydrocarbons were driven off. At Glenboig there are never less than two producers in use, and the difficulty referred to is not experienced. The producers are charged alternately, and while one is giving off hydrocarbons in quantity, the other is producing carbon monoxide. Thus great variation in the quality of the gas is avoided, and to meet any slight variation the air-supply can be regulated to a nicety, so as to give either a reducing or an oxidizing flame. The economical production of a continuous oxidizing flame no doubt requires careful manipulation, as the slightest unnecessary excess of air causes serious loss of heat; but the amount of care required is well within the reach of any ordinary workman. Your clayworker need not have failed. A great success was within his reach if he had gone about it in the right way.'" (*British Clayworker*, November 1903, pp. 277–278.)

Whatever may be said for or against the use of Mond gas for pottery-burning, the study of the complete Mond-gas plant is certainly a lesson in economy, and in the conservation of heat, well worth close attention, for

undoubtedly there is room for many economies in pottery-burning; heat and energy are well known to be going to waste in many directions.

And if special kilns and ovens have to be designed to enable the industry to reap the full benefit of firing with cheap gas, the exercise of inventive faculties will be a healthy exercise, which will confer permanent benefit upon the trade.

But it must not be overlooked that carbonic monoxide gas, even when comparatively dilute, is poisonous, and that many instances of untoward results have occurred.

Two examples reported in the *Stone Weekly News* will suffice:—

"An inquest was held on Wednesday at Liverpool upon Jane Gressier (71), a nun at Mount Vernon Convent, who was found dead in her bedroom on the morning of the 11th inst., having been suffocated through an escape of gas. The top of a gas-stove in the bedroom was found to be defective, and allowed an escape. An interesting point in the case was that the gas supplied by the gas company was admitted to be not pure gas, but to contain 10 per cent. of water-gas, and evidence was given of other cases of gas poisoning since the admixture was adopted by the company. Medical evidence was given as to the danger of the mixture. The jury returned a verdict of accidental death, due to carbon monoxide gas poisoning." (*Stone Weekly News*, 19th February 1904.)

"A FATHER'S SHOCKING DISCOVERY.

"A few days ago an inquest was held on two workmen who were poisoned by inhaling carbon monoxide gas at the ironworks of the Yorkshire Iron and Coal Company, East Ardsley, and another death there is now reported. The victim this time is a boy named Thomas Whitehead (15), who was found dead on Friday night about 9.30. As far as can be ascertained, the boy was last seen alive at 4.25 p.m. by William Reddington, one of the works foremen, whom he assisted. Nothing further appears to have been seen of him until the boy's father discovered him dead in Reggington's office. The office referred to is about 10 yards from the cabin where the two men were found the other week. In the present case the boy was quite dead when found, while in the other case signs of life were evident." (*Stone Weekly News*, 15th April 1904.)

With the object of placing this side of the subject more prominently before those interested, the writer inquired of the Home Office for a return of the deaths from the poisonous effects of carbon monoxide, and was informed that the chief inspector of factories did not know of such return; presumably, then, no statistics have been published by the Government. But the number of deaths of persons sleeping around lime-kilns, and those of the description referred to in the above news-cuttings, are ample evidence of the gravity of

the considerations involved in the adoption of producer-gas as a fuel by the ceramic industry, and, in view of the troubles with lead poisoning, may well cause the manufacturers to move cautiously in this matter.

Sorting and Sizing Tiles.—Various methods of dealing with the output of an oven when the tiles are drawn may be adopted. One of these, the result of many years' tile-manufacturing experience, has been expressed thus:—In drawing the oven the different kinds and sizes may be grouped in the warehouse somewhat as follows:—

(*a*) Bath-tiles, 6-inch by 6-inch, octagonal 6-inch and hexagonal 6-inch.

(*b*) Floor-tiles, 6-inch by 6-inch, octagonal 6-inch and hexagonal 6-inch, with separate rows for each colour and each size.

(*c*) Vitreous tiles, in separate batches according to colour—white, blue, green, pink, etc.

(*d*) Small tiles, $\frac{1}{2}$, $1\frac{1}{16}$; $1\frac{1}{16}$ by $1\frac{1}{16}$; $\frac{1}{2}$, $1\frac{1}{2}$ diag.; $1\frac{1}{2}$ by $1\frac{1}{2}$; $\frac{1}{2}$, $2\frac{1}{8}$ diag; in baskets or in separate batches.

(*e*) Inlaid or encaustic tiles of various sizes may also be stacked up in separate sizes.

(*f*) All other sizes and colours may be "bunged" or stacked up together.

By means of this preliminary separation, it is possible to ascertain approximately the quantity of square yards drawn out of the oven, and to keep a tabulated record thereof, before the sorters have touched the tiles. Afterwards the sorters separate the tiles gently, using a wooden mallet where necessary; and sort them out into best, seconds, thirds, and pitchers, utilizing any straight and true 6-inch by 6-inch, octagonal 6-inch, or hexagonal 6-inch thirds tiles for use as "setters" or "bats" upon which to place newly made tiles when taken from the presses.

After being separated and sorted, the various kinds are placed in their respective pens or heaps, in readiness for the "lookers-out" making up orders.

Sizing may be done on a true-board, or through a gauge or ring, and separations made accordingly.

RECIPES FOR RED FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Red Flooring Body.

Carefully selected fine-grained red "marl" alone, weathered and equalized by turning over, and then blunged with water into a slip of creamy consistency. The slip should be sieved, first through a brass-wire sieve of 60-hole mesh, and afterwards through one of 90-hole mesh, the process being effected either by hand or by machinery, according to extent of works.

No. 2.—Red Flooring Body.

18 cwts. of mixed red marls or clays carefully selected and weathered.
½ „ of finely levigated china-stone.

No. 3.—Red Flooring Body.

10 cwts. of mixed red marls or clays carefully selected and weathered.
12 lbs. finely levigated common ironstone.
14 „ Cornish china-clay.

No. 4.—Red Flooring Body.

10 cwts. siliceous red marl, weathered.
10 „ yellow surface clay.

No. 5.—Red Flooring Body.

8 cwts. Cheltenham red clay.
4 „ Dorsetshire yellow silica clay.
½ „ ground calcined flint.
½ „ Cornish china-clay.

No. 6.—Red Flooring Body.

900 lbs. dark Froghall marl.
300 „ earthenware body shavings.
120 „ ground Cornish china-stone.

No. 7.—Red Flooring Body.

900 lbs. mixed red marls, weathered.
150 „ cane marl, weathered.
150 „ Cornish china clay.
50 „ finely ground glass.

RECIPES FOR CHOCOLATE-COLOURED FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Chocolate Flooring Body.

3 tons mixed red marls or clays, weathered.
50 lbs. levigated "bulldog" iron-furnace waste.
50 „ „ common ironstone.

No. 2.—Chocolate Flooring Body.

18 cwts. mixed red marls, weathered.
30 lbs. levigated common ironstone.
28 pints „ manganese slip.

No. 3.—Chocolate Flooring Body.

8 cwts. siliceous red marl, weathered.
8 „ "Cellarhead" yellow clay.
¾ „ levigated common ironstone.

No. 4.—Chocolate Flooring Body (dark).

8 cwts. siliceous red marl, weathered.
8 „ "Cellarhead" yellow clay.
½ „ levigated common ironstone.
¼ „ „ "bulldog" iron-furnace waste.

No. 5.—Chocolate Flooring Body.

360 lbs. mixed red marls, weathered.
2½ „ levigated common ironstone.
2½ „ „ "bulldog" iron-furnace waste.

No. 6.—Chocolate Flooring Body.

400 lbs. mixed red marls, weathered.
42 „ levigated common ironstone.

No. 7.—Chocolate Flooring Body.

500 lbs. mixed red marls, weathered.
10 „ levigated manganese ore.

No. 8.—Chocolate Flooring Body.

720 lbs. dark Froghall marl.
240 „ blue ball-clay.
240 „ finely ground calcined ochre.
120 „ ground Cornish china-stone.

RECIPES FOR BLACK FLOORING-TILE BODIES

(*For treatment, see Preparation of Bodies.*)

No. 1.—Black Flooring Body.

3 tons mixed red marls or clays, weathered.
260 lbs. levigated "bulldog" iron-furnace waste.
240 „ „ best quality manganese.

No. 2—Black Flooring Body.

18 cwts. mixed red marls, weathered.
100 lbs. levigated manganese ore.
56 „ „ common ironstone.
40 „ „ "bulldog" iron-furnace waste.

No. 3.—Black Flooring Body.

280 lbs. siliceous red marl.
10 „ levigated "bulldog" iron-furnace waste.
10 „ „ manganese ore.

No. 4.—Black Flooring Body.

16 cwts. red marl, of a porous kind when burnt, one that yields a large-sized tile.
3 „ any red, chocolate, or black clay-dusts that have been accidentally mixed.
56 lbs. levigated manganese ore, hard, "pyrolusite."
44 „ „ „ „ soft, "wad."
56 „ „ common ironstone.
40 „ „ "bulldog" iron-furnace waste.

No. 5.—Black Flooring Body.

8½ cwts. mixed red marls, weathered.
3 „ yellow surface clay.
½ „ levigated manganese ore.
½ „ „ "bulldog" iron-furnace waste.

No. 6.—Black Flooring Body.

21 cwts. siliceous red marl, weathered.
7 „ "Cellarhead" yellow surface clay.
1½ „ levigated manganese ore.
1½ „ „ "bulldog" iron-furnace waste.

No. 7.—Black Flooring Body (vitreous, greenish).

14 cwts. siliceous red marl, weathered.
14 „ "Cellarhead" yellow surface clay.
1½ „ levigated manganese ore.
1½ „ „ "bulldog" iron-furnace waste.

No. 8.—Black Flooring Body.

800 lbs. siliceous red marl, weathered.
100 „ levigated ochre.
100 „ „ manganese ore.

No. 9.—Black Body (reputed to be Josiah Wedgwood's).

60 lbs. blue clay.
60 „ ground ochre (possibly marl nodules).
12 „ „ manganese.
10 „ „ china-stone.
12 „ „ iron scales.

RECIPES FOR DARK DRAB-COLOURED FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Dark Drab Flooring Body.

3 tons cane or buff marl, weathered.
80 lbs. levigated "bulldog" iron-furnace waste.
80 „ levigated manganese ore.

No. 2.—Dark Drab Flooring Body.

6 cwts. black ball-clay.
4 „ siliceous buff ball-clay.
1 „ surface yellow clay.
½ „ levigated calcined manganese ore.

No. 3.—Dark Drab Flooring Body.

12 cwts. common ivory ball-clay.
6 „ siliceous buff ball-clay.
1 „ surface yellow clay.
¼ „ levigated calcined manganese ore.
¼ „ „ "bulldog" iron-furnace waste.

RECIPES FOR LIGHT DRAB FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Light Drab Flooring Body.

3 tons cane or buff marl, from the coal-measures.
70 lbs. levigated "bulldog" iron-furnace waste.
70 „ „ manganese ore.

No. 2.—Light Drab Flooring Body.

$7\frac{1}{2}$ large barrowfuls buff marl, from coal-measures.
1 „ „ red marl.
48 pints of ground manganese in slop state.

Note.—One-fifth of this body may consist of dirty white body-clay scraps, or dirty "buff" or "drab" coloured body scraps. Also by substituting cane or buff marl for the red marl, a grey body is produced.

No. 3.—Light Drab Flooring Body.

18 cwts. buff or cane marl, weathered.
$2\frac{1}{4}$ „ siliceous red marl or clay.
48 pints ground manganese in slop state.

No. 4.—Light Drab Flooring Body.

24 cwts. superior cane marl, weathered.
$\frac{1}{4}$ „ levigated manganese ore.
$\frac{1}{4}$ „ „ "bulldog" iron-furnace waste.

No. 5.—Light Drab Flooring Body.

4 cwts. Leckhampton red clay.
4 „ common ball-clay.
2 „ dark orange buff marl.
$\frac{1}{4}$ „ levigated manganese ore.

RECIPES FOR FAWN-COLOURED FLOOR-TILE BODIES.

No. 1.—Fawn Flooring Body.

1 ton buff or cane marl, weathered.
1 „ red marl, mixed, weathered.
20 lbs. levigated Jersey china-stone.

No. 2.—Fawn Flooring Body.

15 cwts. buff or cane marl, weathered.
6 „ brightest red-coloured marl or clay.

No. 3.—Fawn Flooring Body.

8 cwts. Dorsetshire siliceous yellow clay.
2 „ superior cane marl, weathered.
$\frac{1}{2}$ „ ground Cornish china-stone.

RECIPES FOR BUFF OR CANE-COLOURED FLOOR-TILE BODIES.

No. 1.—Buff Flooring Body.

10 cwts. superior buff or cane marl, weathered.
1 „ common vitreous ivory ball-clay.

No. 2.—Buff Flooring Body.

4 cwts. siliceous buff ball-clay.
6 „ common ivory ball-clay.

No. 3.—Orange Buff Flooring Body.

4 cwts. dark cane marl, weathered.
2 „ ground white earthenware pitchers.
½ „ ground calcined flint.

No. 4.—Buff Flooring Body.

20 cwts. buff or cane marl, weathered.
60 lbs. ground china-stone.
30 „ ivory ball-clay.
10 „ ground calcined flint.
65 „ red marl, weathered.

No. 5.—Buff Flooring Body.

9 cwts. ivory ball-clay.
3 „ siliceous buff ball-clay.
3 „ siliceous yellow clay.
1 „ red clay or marl, weathered.

No. 6.—Buff Flooring Body.

12 cwts. pulverized fireclay, weathered.
2 „ ball clay, common quality.
½ „ red marl, weathered.

No. 7.—Buff Flooring Body.

600 lbs. cane marl, weathered.
50 „ ground felspar.
20 „ ball-clay.
10 „ ground yellow ochre.

No. 8.—Buff Flooring Body.

1000 lbs. Berryhill marl (coal-measures).
220 „ ground Cornish china-stone.
280 „ ball-clay.

No. 9.—Best Cane Flooring Body.

1000 lbs. superior cane marl, weathered.
150 „ ball-clay.
150 „ ground Cornish china-stone.

No. 10.—Cane Flooring Body.

700 lbs. superior cane marl, weathered.
100 „ potter's clay shavings, "ivory" or "cc."

No. 11.—Cane Flooring Body.

900 lbs. cane marl, weathered.
300 „ "tough tom" surface clay.
50 „ ground glass.

No. 12.—Cane Flooring Body.

Superior cane marl, alone, selected and weathered.

RECIPES FOR CREAM-COLOURED FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Cream Flooring Body.

4 cwts. ivory ball-clay.
2 „ ground calcined flint.
1 „ „ Cornish china-stone.

No. 2.—Cream Flooring Body.

4 cwts. ivory-ball clay, common quality.
2 „ ground calcined flint.

No. 3.—Cream Flooring Body.

6 cwts. ivory ball-clay.
6 „ ground calcined flint.
3 „ „ Cornish china-stone.

No. 4.—Light Cream Flooring Body.

6 cwts. black ball-clay (Dorsetshire).
6 „ finely ground silica rock.
2 „ ground Cornish china-stone.

No. 5.—Cream Flooring Body (deep tint).

6 cwts. ivory ball-clay, common quality.
6 „ finely ground silica rock.
2 „ ground Cornish china-stone.

No. 6.—Cream Flooring Body.

6 cwts. ivory ball-clay, stained.
6 „ finely ground silica rock.
2 „ ground felspar.

RECIPES FOR WHITE FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

No. 1.—White Flooring Body (for hard fire).

448 lbs. blue ball-clay (Dorset).
448 „ Cornish china-clay.
220 „ ground calcined flint.
448 „ „ Cornish china-stone.
100 „ „ felspar.

N.B.—If it is desired to increase the whiteness, add half a pint of blue body-stain in the slip state at 26 oz. to pint (see page 517).

No. 2.—White Flooring Body (for medium fire).

3½ cwts. levigated felspar.
4 „ Cornish china-clay, best quality.
3½ „ ground calcined flint.
2 „ blue ball-clay (Dorset).
2½ „ ground Jersey china-store.

No. 3.—White Flooring Body (vitreous for easy fire).

8 cwts. levigated felspar.
4½ „ ground Cornish china-stonε.
3¾ „ Cornish china-clay, strong.
4½ „ blue ball-clay (Devonshire).

No. 4.—White Flooring Body (vitreous).

160 lbs. ground felspar.
130 „ blue ball-clay.
120 „ Cornish china-clay, strong.
90 „ ground Jersey china-stone.
50 „ ground Cornish „

No. 5.—White Flooring Body (wet mixing).

11½ inches ball-clay slip at 24 oz. to pint.
6 „ china-clay „ „ 26 „
3½ „ slop flint „ 32 „
4 „ „ stone „ 32 „
40 quarts slop felspar „ 32 „
(Area of mixing ark, about 4 feet by 4 feet.)

No. 6.—White Flooring Body.

200 lbs. best ball-clay.
200 „ ground calcined flint.
100 „ ground china-stone.

No. 7.—White Vitreous Body (to burn at Cone 13).

(A short vitreous body, recipe as given p. 358, *Trans. American Ceramic Soc.*, vol. v.)

Chemical formulæ, $\left.\begin{matrix}0{\cdot}130\ K_2O \\ 0{\cdot}052\ CaO\end{matrix}\right\}$ $\left.1{\cdot}00\ Al_2O_3\right\}$ $6{\cdot}26\,SiO_2$.

1200 lbs. china-clay.
1200 „ ground flint.
400 „ ground felspar.
28 „ whiting „

The absence of ball-clay was made up for by ageing the prepared body under conditions favourable to bacterial action.

RECIPES FOR BLUE FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Blue Flooring Body.

10 lbs. of No. 2 vitreous white body slip at 28 ozs. to pint.
1¾ ozs. finely levigated blue stain, as below.

Blue Stain.

4 lbs. cobalt oxide
8 „ zinc oxide
2 „ felspar
2 „ flint
} calcined and ground.

No. 2.—Blue Flooring Body.

48 lbs. of No. 4 white tile-body slip.
1 „ of finely ground blue stain (see No. 1 blue).

No. 3.—Blue Flooring Body.

5 cwts. of No. 1 white floor-tile body.
26 pints of blue stain slip at 26 ozs. to pint (see No. 4 blue).

No. 4.—Blue Flooring Body.

198 lbs. blue ball-clay (Dorset).
120 „ Cornish china-clay.
$77\frac{1}{2}$ „ ground calcined flint.
$68\frac{1}{2}$ „ ground china-stone.
$13\frac{3}{4}$ pints slop felspar at 32 oz. per pint.
12 lbs. blue stain (see below).

Blue Stain (to be used 26 ozs. to pint).

60 lbs. white oxide of zinc.
5 lbs. prepared oxide of cobalt.
} Calcine and grind.

No. 5.—Blue Flooring Body.

32 lbs. felspar, ground.
18 „ Cornish china-stone.
17 „ china-clay.
18 „ ball-clay.
$3\frac{1}{2}$ „ ground calcined flint.
$1\frac{1}{4}$ „ blue stain (same as for No. 1 body).

RECIPES FOR GREEN FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Green Flooring Body.

112 lbs. white vitreous tile-body No. 2.
9 „ green oxide of chrome, finely ground.

NO. 2.—GREEN FLOORING BODY.

80 lbs. white vitreous tile-body No. 2.
5 „ green oxide of chrome, finely ground.
½ „ blue stain, finely ground.

NO. 3—GREEN FLOORING BODY.

10 lbs. No. 2 white vitreous body slip at 28 ozs. to pint.
5 ozs. green oxide of chrome, finely ground.
½ „ blue stain, finely ground.

NO. 4.—SEA-GREEN FLOORING BODY (a suggestion).

10 lbs. silver-grey vitreous body No. 1.
10 „ green „ „ No. 1.
10 „ white „ „ No. 2.

NO. 5.—SEA-GREEN FLOORING BODY (a suggestion).

10 lbs. green vitreous body No. 1.
10 „ white „ „ No. 2.
2 „ bronze „ „ No. 1.

RECIPES FOR SAGE-GREEN FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

NO. 1.—SAGE-GREEN FLOORING BODY.

112 lbs. clean buff or cane marl, weathered.
5 „ blue stain, finely ground.

NO. 2.—SAGE-GREEN FLOORING BODY.

112 lbs. superior cane marl, weathered.
112 „ ivory ball-clay (Dorset).
10 „ blue stain, finely ground.

NO. 3.—SAGE-GREEN FLOORING BODY.

40 lbs. superior cane marl, weathered.
10 „ ivory ball-clay (Dorset).
1 „ blue stain, finely ground.

RECIPES FOR CELADON FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Celadon Flooring Body.

48 lbs. No. 2 white vitreous body.
$\frac{1}{2}$ " oxide of copper, finely levigated.
$\frac{1}{4}$ " blue stain, finely ground.

No. 2.—Celadon Flooring Body.

12 lbs. No. 2 white vitreous body slip at 28 ozs. to pint.
1 oz. oxide of copper, finely levigated.
$\frac{1}{2}$ " blue stain, finely ground.

No. 3.—Celadon Flooring Body (a suggestion).

10 lbs. vitreous green body No. 2.
10 " " white " " 2.
5 " " blue " " 1.

No. 4.—Celadon Flooring Body (a suggestion).

10 lbs. vitreous celadon body No. 1.
5 " " white " " 2.
2 " " blue " " 1.

RECIPE FOR DOVE FLOOR-TILE BODY.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Dove Flooring Body.

24 lbs. superior cane marl, weathered.
10 " best ball-clay.
2 ozs. oxide of cobalt, finely levigated.

RECIPES FOR SILVER-GREY FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Silver-Grey Flooring Body.

112 lbs. No. 2 white vitreous tile-body.
1 " levigated "bulldog" iron-furnace waste.

No. 2.—Silver-Grey Flooring Body.

48 lbs. white vitreous body slip at 28 ozs. to pint.
3 ozs. levigated "bulldog" iron-furnace waste.

RECIPE FOR BRONZE-COLOURED FLOOR-TILE BODY.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Bronze Flooring Body.

$9\frac{1}{2}$ lbs. white vitreous tile-body No. 3.
$\frac{1}{2}$ " grey oxide of nickel.

RECIPE FOR YELLOW FLOOR-TILE BODY.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Yellow Flooring Body.

$9\frac{1}{2}$ lbs. white vitreous tile-body No. 3.
$\frac{1}{2}$ " yellow rutile, very finely ground.

RECIPES FOR SALMON-PINK FLOOR-TILE BODIES.

(*For treatment, see Preparation of Bodies.*)

No. 1.—Salmon-Pink Flooring Body.

12 lbs. No. 2 white vitreous body.
1 " Japanese red, calcined and ground.

No. 2.—Salmon-Pink Flooring Body.

20 lbs. No. 2 white vitreous body-slip at 28 ozs. to pint
12 ozs. Japanese red, calcined and ground.

RECIPE FOR ROSE-PINK VITREOUS TILE-BODY.

(*a*) Stain.

$16\frac{7}{8}$ lbs.	barium carbonate	ground in water at the mill.
$6\frac{3}{8}$ "	whitening	
$5\frac{1}{2}$ "	U.G. pink colour	

(*b*) Base Body.

$12\frac{11}{16}$ lbs.	Cornish china-clay	made into a slip with water and sieved.
$2\frac{1}{8}$ "	Cornish china-stone	
$25\frac{5}{16}$ "	ground calcined flint	
$29\frac{1}{2}$ "	blue ball-clay (Devonshire)	

(*c*) Complete Body.

All of (*a*) and (*b*) intimately mixed together, and passed through fine lawns, such as 16 silk lawns or 120^h brass-wire sieves.

Note.—Tiles made of the above body composition must be specially "placed" for burning in single layers, face upwards, on sanded bats or setter-tiles, but no sand must be scattered on the surface of the pink tiles themselves. To enable several tiers to be placed in the same saggar, small props are interposed between the bats or setter-tiles. These rose-pink tiles are not usually made in larger sizes than $1\frac{1}{2}$ inch by $1\frac{1}{2}$ inch.

RECIPES FOR JASPER BODIES FOR INLAYING SLIPS.

White Jasper Body for Inlaying Tiles.

$8\frac{1}{2}$ lbs. best barytes, finely ground
$4\frac{1}{2}$ „ blue ball-clay
3 „ china-clay
2 „ ground calcined flint
4 „ „ Cornish china-stone
$2\frac{1}{2}$ „ soda-lime glass, ground
$\frac{1}{2}$ „ plaster of Paris

mixed with water, soaked, lawned, and mellowed.

Blue Jasper Body for Inlaying Tiles.

$8\frac{1}{2}$ lbs. best barytes, finely ground
$4\frac{1}{2}$ „ blue ball-clay
3 „ china-clay
2 „ ground calcined flint
4 „ „ china-stone
$2\frac{1}{2}$ „ soda-lime glass, ground
$\frac{1}{2}$ „ plaster of Paris
$\frac{1}{2}$ „ black oxide of cobalt, finely ground

mixed with water, soaked, lawned, and mellowed.

Pink Jasper Body for Inlaying Tiles.

8 ozs. lime
8 „ glass
8 „ U.G. pink

finely ground at the mill.

Then to the above add :—

1 pint ball-clay slip at 24 ozs. to pint.
$\frac{1}{2}$ „ slop stone at 32 ozs. to pint.

Muspratt mentions six different formulæ for white jasper bodies, thus:—

	I.	II.	III.	IV.	V.	VI.
Sulphate of barytes,	150	40	30	50	32	160
China-clay,	35	...	...	15	10	60
Blue-clay,	45	20	12	35	25	90
Flint,	35	...	3	10	8	40
Gypsum,	6	...	...	...	1	8
Cornish stone,	50	20	20	...	7	...
Bone,	...	...	...	25	...	...

and remarks that the stain used for the blue colour is one part of cobalt to from fifty to seventy-five parts of body, according to the depth of colour required. Other coloured jaspers are obtained by the addition of other oxides to the white bodies; green jasper being obtained by the admixture of oxide of chromium.

RECIPE FOR BLUE BODY-STAIN.

(For use in white earthenware bodies.)

9 lbs. black oxide of cobalt. 9 „ Cornish china-stone. 1 „ sulphate of baryta.	Calcine in biscuit oven forebung, then grind in water, and use at 26 ozs. to pint.

CHAPTER VIII.

MOSAIC (MUSEAIC) PAVEMENTS AND MURAL DECORATION.

"*Mosaic is the true painting for eternity.*"—GHIRLANDAIO.
"*Every hour of my life these mosaics become more precious.*"—RUSKIN.

CONTENTS.—Definitions—Chaldean cones—Egyptian inlaid work—Grecian—Roman—Glass mosaics—Byzantine—Italian—Venetian—British—St. Paul's Cathedral—Marble mosaic—Grecian—Roman—Italian—Saracen—Indian—Modern European—Ceramic mosaic—Roman—Blashfield—Prosser—Minton—Contemporary.

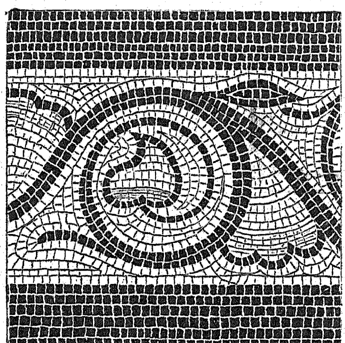


FIG. 228.—Mosaic from Cirencester. (*Cassell's Tech. Ed.*, vol. iii. p. 201.)

THE term MOSAIC, though in general use, does not appear so suggestive and appropriate for the work as could be desired. It demands a too abstruse tracing back *via* the French *mosaique* to the Greek *mousaikon* (polished) to prevent the average British intellect associating it with certain incidents of Biblical history, and so ending in a barren and negative etymology without sense.

Some dictionaries, however, suggest the alternatives *musaic* or *museaic*, from the Latin "*opus musivum*" and "*pictura de musivo*"; hence "*musivarii*." These immediately suggest ideas of grace and elegance, of things pertaining to the fine arts; the optional terms, therefore, are perhaps the more correct. A learned reference to the derivation and use of the term occurs in a letter by Sir George Birdwood, K.C.I.E., in the *Jour. Soc. Arts*, 1st March 1901, p. 265, which is worth looking up by any who are sufficiently interested.

Mosaic has been defined by Hayler as the combination of different-coloured small pieces of hard substances, such as marbles, stones, pastes of glass, etc., to form a design which may be either a geometrical pattern or a picture. Professor Delamotte is more explanatory. He says:—"By mosaic we understand the art of putting together pieces of various materials, either white or parti-coloured, in such a way as to form definite patterns. Just as a musical

note differs from a mere sound by the fact that there is a certain rhythmical arrangement of pulsation instead of vibration repeated at no certain interval, so does a mosaic pavement, for instance, differ from an ordinary pavement in having the materials arranged in a certain order according to their shape and colour. We do not wish to imply that pavement is the only purpose to which mosaic can be applied, but it gives the readiest means of explaining what we mean by mosaic." (*Cassell's Tech. Educator*, vol. iii. p. 199.)

Loftus found that the Chaldeans had used a kind of mosaic mural decoration formed of cones, placed in the walls with their bases only showing; but as these were frequently in connection with great ancient burial-grounds, he supposed they had some particular signification other than that of mere ornamentation.

According to Hayler, the art of mosaic was practised in Egypt from very early times. The Greeks, too, made use of it, but it was comparatively late in their history when their artists began; nevertheless, they ultimately became its chief exponents, using marble at first, and in course of time introducing glass tessellæ. (See *Jour. Soc. Arts*, 15th February 1901.)

The Romans made very extensive use of mosaic, principally for floors of villas and public buildings, leaving many beautiful examples, which, together with the Græco-Roman or Byzantine glass mosaics, form the classical bases of almost all mosaics of our own time.

The Saracens, entering into the heritage, extended its use in India, Western Asia, Africa, Sicily, and Spain, their mosaics being composed sometimes of marble, sometimes of glass, sometimes of fragments of enamelled tiles.

Italian, Venetian, and French examples of later date are well known; and to-day mosaic is in use throughout the length and breadth of English-speaking and European civilization of both hemispheres.

Mosaic assumes so many phases, may be composed of so many different materials, applied as a decorative element in such various ways, is the victim of such incompatible personal predilections, a reviewer inevitably discovers the choice even of a classification far from easy. He may consider it by periods, by uses, by styles, by materials, or by the technique of fixing. Sir Digby Wyatt is said to have treated the subject under seven headings, viz., classical, Latin, Byzantine, Græco-Italian, Italian monumental, Italian portable, and Florentine or *pietra-dura*. But the classification that commends itself for our purpose is the one relating to the predominating material: thus, glass mosaic, marble mosaic, ceramic mosaic.

Occasionally fragments of pearl, ivory, and precious stone were introduced, but these partake more of the nature of "*inlaying*" and "*cloisonné*."

Glass Mosaic.—Fragments of precious stones, cut to complex facets, were mounted by prehistoric Egyptian goldsmiths in beautifully wrought jewellery

ages ago. These furnish the facts of many of those true romances so inimitably told by Dr. Flinders Petrie.

In the *Times* of 9th March 1901 he described the gold-work and ivories which once formed part of the toilet objects of Menes, and the four splendid bracelets found on the forearm of the queen of King Zer (Menes' successor), in which cast and chased gold alternate with turquoise, lazuli, and amethyst; found in the tombs of Abydos, and dating back six thousand five hundred years.

Then at Dahshur M. De Morgan found like treasures of later date. Of these Mr. John Ward, F.S.A., writes:—"Every tomb had been rifled in ancient times, and in clearing out the shafts several thieves' entrances were discovered . . . . but the robbers had done their nefarious work hurriedly, and M. De Morgan's eye detected several tombs that had only been partially opened. The treasure was found intact in one of those, which the discoverer showed me himself. I was lowered down, by a stout rope slung from under my arms, into the shaft—about 40 feet, cut in the solid rock. At the bottom we found a tunnel. . . . . There were openings on either side, each containing an empty stone coffin, ... Underneath one tomb, that of a royal princess, a wooden coffer was found containing £40,000 worth of jewellery, gold, and precious stones. The ornaments were beautifully designed, and of perfect skill in workmanship and in the most exquisite taste. Another tomb also had a somewhat similar treasure, but not quite so rich. The jewellery, or some of it, had belonged to King Usertesen, and bore his cartouche in gold inlaid with sapphire, lapis-lazuli, turquoise, carnelian, and other precious stones. These treasures are now preserved in the Cairo Museum." (*Pyramids and Progress*, p. 52, Eyre & Spottiswoode.)

When Akhenaten built the new city at Tell el Amarna (B.C. 1400), the architects made use of jewellers' devices to enrich the structure of the palace; capitals of the columns were inlaid with fragments of gorgeously coloured glasses, and the spaces between were gilt. (See *Tell el Amarna*, p. 10, E.E. Fund.)

Such, apparently, were the early beginnings of decorative glass mosaic.

The lavish use of glass mosaic for conventional and allegorical mural embellishment during the Middle Ages, within the range of Byzantine influence, has been described by C. H. Townsend, Esq., F.R.I.B.A., in his *Cantor Lectures*, 1893. Respecting St. Sofia (Constantinople), he said:—"The building, commenced in 532 and finished eight years later, was destined by Justinian to eclipse all hitherto existing Christian churches. . . . . He called to his aid for the beautifying of his new Basilica of St. Sophia the services of the best artists . . . . who lined its interior with magnificent marbles, and covered its upper walls and ceilings with the most brilliant of mosaics. These, or many of them, to-day lie hid under the coats of whitewash due to Mohammadan

bigotry and ignorance. But in 1847, during the course of some repairs to the structure ordered by the then Sultan, Herr Von Salzenburg had a fortunate opportunity of making drawings of some of them. These help us to see how glorious a building must this have been, of which its imperial builder is reported to have said, 'Solomon, I have surpassed thee.'" Mr. Townsend further quotes from some unnamed author respecting St. Sofia:—"The pavements glistening like sheets of silver, the many-tinted marble pillars shining like a marble firmament, the walls sheeted with mosaic executed with all the art that the age afforded. A giant effigy of Christ, the Virgin and Saints over the high altar, and four mighty archangels enfolded in purple wings, in the spandrels of the dome, looking down on the sanctuary containing the sacred vessels and on the jewelled veil dividing it from the nave." (*Cantor Lect.*, p. 17, 1893.)

But we infer from Mr. Townsend's remarks on 23rd March 1901, before the R.I.B.A., that the whitewash may be not so much a concealment of as a substitute for the now vanished mosaics. He suggests the probability, as the result of personal inspection, that the mosaics themselves have absolutely vanished. (See p. 227, "Art of Pictl. Mosaic.")

A list of many examples of glass mosaics will be found on p. 210, *Jour. Soc. Arts*, 15.2.1901, and in the ("Art of Pictl. Mosaic") *Journal R.I.B.A.*, third series, vol. viii. No. 10, 23rd March 1901, p. 227.

Of the use of glass mosaic by the Saracens, Sir George Birdwood, K.C.I.E., C.S.I., M.D., has told us that "When the Saracens first invaded Palestine they were greatly struck . . . . by the ornamentation of the Church of St. Helena at Bethlehem with glass mosaic; while one of the conditions of the peace concluded with the Caliph Walid and the Greek Emperor Justinian II. was, according to Ibn Saad (A.D. 844–860), that the latter should furnish the former with a certain quantity of 'fse fysa' for the decoration of the mosque he was building at Damascus, *i.e.*, after the manner of the decoration with coloured and gilded glass mosaic of the Christian church of St. Sophia at Constantinople. From Damascus and Cairo, and subsequently from Baghdad, the art spread everywhere with the religion of Islam—eastward into India, and westward into Spain, where it culminated in unrivalled splendour at Seville and Cordova and Granada." (*Jour. Soc. Arts*, 1st March 1901, p. 265.)

Of the Mosque of Omar, Jerusalem, Mr. T. R. Spence wrote:—"The interior . . . . is a dream of luscious colour in mosaic, gold, iron, and marble. The vast dome, rising from a bold and simply profiled cornice, is covered with mosaic, kept low in tone, yet bristling with delicate scintillations. . . . . The whole expanse of mosaic is in gradations of red, blue, green, gold, and silver. . . . . The simple semi-geometrical forms used throughout on the Shrine of Omar are so satisfactory in effect, that a doubt arises whether figure-subjects

as used in St. Mark's lend themselves to the supremest triumphs in the decorative use of mosaic." (*Arch. Review*, December 1899.)

Of the wall-mosaics of Cordova (Spain), Stanley Lane-Poole writes:—"The porphyry, jasper, and marbles are still in their places; the splendid glass mosaics, which artists from Byzantium came to make, still sparkle like jewels on the walls." (*The Moors in Spain.*)

Such of the mosaics of Ravenna as escaped the depredations of Charlemagne, and those of Rome and of Sicily, are fully illustrated and described by Mr. Townsend. Of the latter he says:—"At Monreale the church was, as Fergusson says, evidently so designed that all other features might be subordinate to this colour-treatment. Lucius III., in 1182, declares that 'its like hath not been constructed by any king even from ancient times'; and the late J. A. Symonds says it is without equal in 'the gorgeousness of a thousand decorative elements subservient to one controlling thought.' (*Cantor Lectures*, p. 10, 1893.)

Respecting early Venetian mosaic, Mr. Townsend remarks:—"It is to the twelfth century that we owe the superb mosaics of Torcello and St. Mark's, Venice. The west wall of the cathedral of the former island is covered with the subject usually reserved for that portion of a church. In six bands, and altogether containing no less than one hundred and fifty figures, are represented the judgment-hall and Paradise, with the Resurrection in the upper portion. . . . . The angels on the right, in the second band, are a charming piece of colour. . . . As a contrast to this crowded and dramatic series, one sees, on turning to the eastern apse, the whole space occupied by a solemn and solitary figure of the Virgin Mary. The two treatments offer to the mosaist a lesson, marked in its distinctness, as to the immeasurable superiority of the simple in design as compared with the complicated. The island of Torcello, then crowded, busy, and rich, was in direct rivalry with Venice. So we might expect to find, as we do, that, more or less in competition with the beautifying of the church on the smaller island, the Venetians were industriously at work on their beloved St. Mark's. . . . . The history of St. Mark was carried out in the chapel of St. Zeno; our Lord, the Virgin, David, Solomon, and the prophets on the dome of the choir; the four rivers of Paradise and the four evangelists in the spandrels of the central dome; the Almighty surrounded by saints in the apse; the Holy Ghost and the nations to whom the Gospel came, in the western dome; St. Clement in the chapel of that name; and above the door here mosaics (signed Petrus and dated 1159) representing the history of Cain and Abel." (*Cantor Lect.*, p. 10.)

The beautiful series of mosaics over the doors of the west front of San Marco, Venezia, he attributes to the thirteenth century; but remarks that only one of them remains, the others having been replaced by inferior works, principally in the seventeenth and nineteenth centuries. For toward the end

of the fifteenth century Townsend asserts that signs of decadence were plainly visible: mosaists of that period being afflicted with that fatal heresy of attempting to meet the painters on the same ground, and thinking their work deserving of praise when it so closely resembled oil-paintings as to be indistinguishable when viewed from a little distance. In the sixteenth century we are told that certain workers, named Zuccati, carried out the panoramic subjects on the soffits of the westernmost arch. But they were suspected of having used the paint-brush; and the Venetian Senate, hearing of the charge, became indignant, and appointed a commission of artists of the highest order, including Titian, Veronese, Tintoretto, and others; this commission affirmed and verified the charge, and the Senate compelled Zuccati Brothers to do the incriminated work over again at their own cost. (*Cantor Lect.*, by C. H. Townsend, p. 15, 1893.)

Thus there is evidence of two of the most dominant religions being instrumental in extending the use of mosaic for architectural ornamentation, during the Middle Ages, from the Ganges to the Rhine.

The resuscitation of the glass industry at Murano in 1856 arose entirely out of a desire to revive mediæval mosaic. Dr. Salviati, in a paper read before the Society of Arts, 14th May 1889, explained it as follows:—"It was the pleasant duty of my father, Dr. Salviati, to give this first impulse and to raise the dormant genius, and give new life and energy to this lovely and brilliant art. . . . . My father was a lawyer of good repute, and, while exercising his professional duties at the Venetian forum, he spent his leisure hours in admiring and studying the sublime works left by his ancient compatriots. It grieved him that such lovely works should be doomed to oblivion, and in the year 1856 he conceived the arduous idea of reviving the mosaic art. . . . . Having associated himself with Lorenzo Radi, of Murano (an artisan who for many years had occupied himself in studying the manufacture of the first material necessary for mosaic), he relinquished his profession of the law, and dedicated all his energies and fortune to the development and perfection of the gold and silver and coloured enamels for the manufacture of Venetian mosaic. Their first joint attempts were so successful as to deserve the highest encomiums from the Royal Academy of Fine Arts in Venice. A committee, consisting of painters, sculptors, and architects, was chosen. . . . . After carefully examining, they declared that the gold, silver, and coloured enamels produced by Dr. Salviati are even superior to the enamels of ancient times." (*Jour. Soc. Arts*, 7th June 1889, p. 627.)

Mr. Hamilton's version of this incident differs only slightly, in that it confers rather more credit on Radi, and states that he applied to Dr. Salviati to help him by supplying means to enable him to revive the mosaic art in Venice. (*Jour. Soc. Arts*, 6.2.03, p. 232.)

The story of the Vatican mosaic studios, as kindly supplied by Mr. Adams, of the Venice and Murano Glass Co. (by permission of Mr. Hamilton), reads as follows :—" In 1640 Urbano VIII. issued an order by which all the splendid oil-paintings existing then in the different chapels of the church should be secured for ever—substituting the same with faithful copies made in mosaic, with the same method followed for the decorations of the dome and the vaults. Orders for execution thereof were given to several artists, to whom, for that effect, a locality was granted, situated behind the Gregorian Chapel, and materials were thereupon furnished to the artists, without, however, any definite purpose to establish a real school.

" In 1727 Benedetto XIII.—all the mosaics decorating the dome (the cupola) and the vaults of the church being completed, and wishing to prosecute and complete the works in mosaic of the large oil-panels which were to be removed from the church—founded the School or the Studio del Musaico within the Vatican Palace, and gave orders to private furnaces for a more regular supply of enamels to be produced exclusively for the studio.

" It is therefore to Benedetto XIII. that the foundation of the celebrated studio is due. He appointed as president of the works the manager *pro tempore* of the Fabrica, and as director the illustrious mosaist Pietro Paolo Cristofari.

" In 1845, finally, Gregorio XVI. gave anew start and a better organization to the studio, both as regards the furniture (supply) of the enamels (called munizione), and the mode of proceeding in forming the contracts of the artistic works to be executed in mosaic, and for the *personnel* as well to be employed in the studio. This was limited to the number of four professional musaicisti and two assistants, to whom all regular wages were fixed. Besides the said quantity of workmen, as prescribed by regulation, two young apprentices have been added, so making *eight*, the number of the working mosaists.

" At one time, *i.e.*, during the period of Gregorio XVI., the enamels were fabricated in a place annexed to the studio in two small ovens ; but the requirements of enamels were so limited, and the expense for the production so large, that soon the ovens ceased to work, and the enamels were acquired in private."

In conclusion, Mr. Adams observes that in translating the foregoing the original has been closely followed at the expense of the English.

The Papal artisans, however, learned the technique apparently too well, for Townsend, commenting upon the work done, observes :—" It is one of the cardinal faults of the modern mosaic-worker, of Italy especially, to be proud of the fact that his . . . . box of tesseræ comprises an infinitude of shades of each colour. Nothing, for instance, can be more absurd nor more opposed to the true principles of the art than to boast, as does the pontifical mosaic studio in Rome, that it has an available stock of twenty-five thousand different

tints for its artists' use. . . . . The work now in hand at St. Paul's only demands a colour-box of about thirty tints." (*Cantor Lectures*, 1893, p. 19.)

A comparatively recent work in glass mosaic in Rome is that by Mr. Burne-Jones, which has been described in the *Times* as follows:—

"There has lately been placed in the American Church in the Via Nazionale, Rome, a mosaic which, according to the unanimous testimony of the Italians themselves, is the most important example of this form of art that recent times have produced. It has been executed by the Venice and Murano Glass Company from cartoons by Mr. Burne-Jones, and it covers the whole of the roof of the apse, a space of not less than 800 square feet. The subject may be briefly described as Christ enthroned in the centre of the New Jerusalem, with mysterious angel forms around and about him, and, on either hand, keeping watch over the gates of the heavenly city, the archangels, Michael and his peers.

"The Lord is presented in the freshness and eternal youth of the glorified body, 'sitting upon a throne, high and lifted up,' as in the vision of Isaiah. His face is beardless, as in the mosaics at Ravenna and in the earliest pictures of the Catacombs. His pierced right hand is raised in benediction; and in the hollow of his left he bears the world, a wonderful ball like those in the famous picture of 'The Days of Creation.' Around his head are angels whose wings are of sapphire blue—the colour of intelligence, as the old hagiographers explained; while those near the heart have wings of red, the colour of love, and those about the feet are amethystine. His feet rest on a rainbow, and below from the foundation of the throne there flow the four rivers of the Gospel, which spread abroad and cover all the world. Above, and melting into distance, are the 'multitude of the heavenly host'; while on either hand are the archangels. Michael is a glorious figure in armour; Uriel holds the sun; Gabriel bears the lily of the Annunciation; Chemuel, the angel of the Sangreal, stands next him with the sacred cup; and Zophiel, to his left, holds the moon. These great figures stand before the gates, and the wall between them is of shining gold. But one door is black and unguarded; it is that through which, according to the legends in which the artist has steeped himself, Lucifer went out on the fatal day when he drew after him to ruin a third of the host of Heaven.

"The peculiar genius of Mr. Burne-Jones has never found a more appropriate field than here. Whatever may be thought of his pictures, as pictures, few voices have been raised against his designs for stained glass; and *a fortiori* his power of imagining noble forms which have their counterpart elsewhere than in mortal experience finds a proper field in designing for mosaic. It may even be said that he is almost the first of modern artists who has really understood the limitations of this particular art. The workmen of the Venice and Murano Glass Company, excellent and skilful in their craft, have often been

set to do work that is quite unsuited to it; to execute complicated designs of the so-called 'historical' sort, of which the broken lines and jumbled colours have nothing in common with the gravity, inflexibility, and stiffness of mosaic. It is interesting to learn that the workmen at once understood the difference when they were set to execute Mr. Burne-Jones' design, and that their enthusiasm and patience in carrying out the task—which occupied fifteen months of continuous labour—has been beyond all praise.

"The Roman artists and critical journals have had much to say in commendation of the work, and have hardly yet got over their surprise that it should have been designed by an Englishman. We understand that the artist has made several more drawings—'The Tree of Life,' 'The Annunciation,' and 'The Nativity' being among them—which will be executed in mosaic for the decoration of the great arches of the church, as funds come in." (*The Times*, 14th April 1886.)

As to England's share in the art of glass mosaics, Mr. Harry Powell tells us that a certain English barrister, named Charles Winston (born 1814, died 1864), was the principal instrument in bringing about the renaissance of stained glass in England, and from this he led on to the use of glass mosaics; for, says Mr. Powell, "A letter written by Winston in November 1854 forms a link between his work and that of Sir W. B. Richmond. He writes:—'Dear Powell,—I have at last got some specimens of the glass-mosaic work from St. Sophia at Constantinople, and from St. Paul's at Rome, which I have given to Mr. Clark to analyse, and I doubt not you will soon be able to produce the same yourself." It was long before this prophecy was fulfilled. A period followed devoted to experiments in the manufacture of enamels and in technique. . . . . Subsequently, panels of glass pictorial mosaic were erected at South Kensington Museum, and pavements of glass mosaic were put down at South Kensington, at the Society of Arts, and in several churches. In 1884 a large panel, representing the central group of Raphael's 'Disputa,' was put up on the east wall of the Morning Chapel of St. Paul's Cathedral, and in 1887 Holman Hunt's picture of 'Christ with the Doctors in the Temple' was translated into mosaic for the reredos of Clifton College Chapel. Both these works were executed in what is known as the 'New Venetian' method, *i.e.*, they were treated as panel-pictures and worked in a workshop. In 1891 Sir William Richmond, R.A., was commissioned to carry out the decoration of choir of St. Paul's Cathedral in glass mosaic. A study of these mosaics (all of which, with the exception of two angels of the Passion at the extreme east of the choir, were executed *in situ*) will prove the superiority of Sir W. Richmond's method of working." (*Jour. Soc. Arts*, 12th June 1903, p. 641.)

This brings us to the consideration of that noteworthy example of purely British glass mosaic executed in 1895 and 1896 by Sir W. B. Richmond in the choir of St. Paul's Cathedral, an example of which every English-speaking

nation may justly be proud, since the design, material, and work alike are British.

Sir W. B. Richmond having himself given a full account of it in a paper read before the Society of Arts on 28th May 1895, the most accurate and complete description is easily accessible. Respecting materials he remarks:—"My thanks are due to Mr. Harry Powell for his unremitting labour to give me what I wanted in the glass tesseræ. . . . . I venture to think that in all respects the materials supplied by Messrs. Powell[1] for my work are first-rate, equal, indeed, to any which were supplied to the mosaic artists of the best periods, Greek or Italian."

The ruling principles by which he was guided in his great work he tersely lays down thus:—"Against pictorial mosaic I resolved to set my face, and adhere to the principles of design and execution which prevailed in Italy, Greece, and Asia Minor during the classical times of the Byzantine empire. And while adhering in principle to severe methods of design and simplicity of colouring, to accept and make use of the modern spirit of antiquarian research, I determined to follow the precepts of the great masters, by being accurate in drawing, and, according to my lights, noble in my choice of form. But perhaps my most important point, as it appeared to me to be, was that our metropolitan church must be decorated by English, and not by Italian labour."

Sir W. B. Richmond then mentions another point upon which some determination upon his part had to be exercised, namely, the question of applying the mosaic tesseræ direct and *in situ*, or on paper to be subsequently reversed on the walls.

Following the old masters, he determined to execute the work directly on the walls, guided by the aphorism, "Just as a building is erected where it is to stand, so every portion of the decoration of that building, wherever it has relationship to the walls or to the structure, should be executed where it is to remain, in the light and under the conditions of its environment."

He confesses to some difficulty in getting others who were concerned to agree; but eventually he successfully carried his idea through, and found it took about half the time of the paper method. Then he facetiously observes: "It is wonderful how quickly the modern mind is accessible to art when it has once grasped the fact of its relation to profit, but you must indelibly prove the profit before the artistic sense is touched." (*Jour. Soc. Arts*, 21st June 1895, p. 720.)

Respecting medium or mastic or cement, in a subsequent lecture at the Institute of British Decorators Sir W. B. Richmond unburdened himself thus:—"He found the receipt for the cement by accident in the library at Bologna. The cement which was used in the decoration of the baptistery at

[1] Messrs. James Powell & Sons, of Whitefriars Glassworks, 26 Tudor Street, Whitefriars, near Ludgate Circus, London.

Florence was composed of wax, lime, and resin. It was very good for its purpose, for it kept sufficiently moist for five to eight hours, and could during that time be worked as wax, and then it became as hard as stone and did not shrink." (*Builder*, 14th March 1903.)

Such cement, Mr. Townsend says, is admirable for internal work, but for external work its use is not to be recommended.

Other important examples of modern glass mosaics are the frieze of Horniman's buildings, designed by Mr. Anning Bell; the frieze in the White-

FIG. 229.—Mosaics, St. Paul's Cathedral. (*By permission of Sir W. B. Richmond, A.R.A.*)

chapel Art Gallery, designed by Mr. Walter Crane; and that of the Verdi Memorial at Milan, fixed last year by the Venice and Murano Glass Co.

The few small panels of mosaic on the façade of Leamington Town Hall, although disconnected and almost lost in the general architectural effect because of their meagre proportions, nevertheless shine like gems and glitter like gold among the dull brickwork; and when once the eye finds them, a delightfully refreshing sensation is experienced, causing a sigh for more, and awakening imaginings of glorious possibilities if such material were applied on a more liberal scale.

As to the *technique*, for this publication, a few gleanings from Mr. Hamilton's very practical observations will be sufficient. He said:—"Speaking broadly, there are two methods of construction:—

"(1) The old method, viz., that of fixing the tesseræ on the wall directly and one by one.

"(2) The new method, whereby the mosaic is first executed on paper and thence transferred to the wall.

"The *old method* is simple enough: the wall destined to receive the mosaic is prepared with cement, the cartoon is outlined on the cement, and the mosaists, with the cartoon before them . . . . place the tesseræ on the wall one by one. It is needless to say that under certain conditions the very finest mosaics can be . . . . produced by this method. The ancient mosaists, it would seem, invariably employed it. . . . . The first works executed in England by the Venetian mosaists were so executed . . . . but it was soon made clear that, unless some less expensive and more expeditious means could be devised for executing and fixing mosaics, very little could be done to advance the art."

After noting the inconveniences of the old method, such as the necessity for constant personal supervision of the artist-designer, sending first-class workmen to work away from home, difficulties of weather, light, and position when actually applying the work, Mr. Hamilton continues:—"I now come to the new method. The Venetian mosaists having decided to abandon the application of the old method to the construction of *decorative* mosaics, adopted, developed, and, after many costly experiments, brought to perfection the method which has become associated with their name, and which they have applied to nearly all the large decorative works executed by them during the past thirty years. . . . . To go a little into detail: the studio should always be well lighted and well ventilated. The workers are under the control of an artist, who is also an experienced mosaist. . . . . The working mosaists are divided into grades or classes. The workers in the first grade work on those parts of a mosaic which require the most careful treatment, such as the face, hands, and feet of a figure; those in the second grade work on ornaments and drapery; those in the third grade have given to them the execution of simple backgrounds, and so on—each man being given that work which he is best fitted to perform.

"When a cartoon is brought into the studio, it is traced and reversed on coarse brown paper. This reversed tracing is then cut up into pieces of irregular shape, and these pieces are distributed among the various grades of workers. The cartoon is then hung up so that it may be seen by all, and the workers being comfortably seated at their desks with a small anvil, a small hammer, some paste, and the enamels they will require by their side, the work begins. Each worker having carefully noted the colours and the

size and shape of the tesseræ required for his part of the cartoon, proceeds to cut his enamels accordingly, and to place them with their proper faces downwards on to the plain tracing before him, and to attach them thereto with common paste.

"With the exception of the tesseræ used for metal backgrounds (to which I shall refer later on), each tesseræ is the same in colour throughout, and all the tesseræ are of equal thickness, and are evenly shaped from top to bottom. When, therefore, they are placed on the paper 'face downwards' there

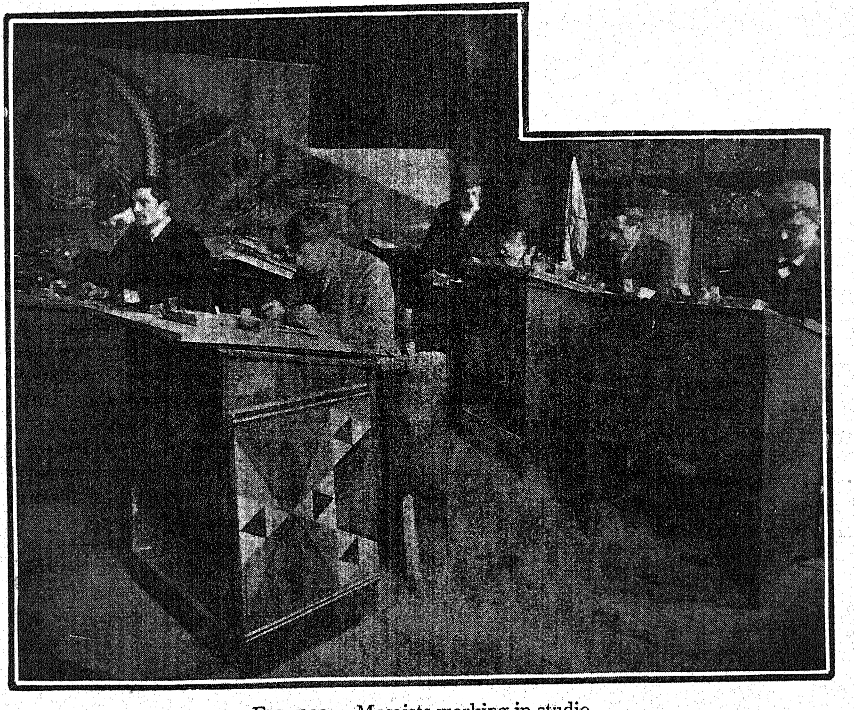


FIG. 230.—Mosaists working in studio.

remains under the eye of the worker the exact counterpart of the work he has executed. . . . . Metal backgrounds sometimes require a slightly different treatment. Owing to the construction of 'metal cakes,' the metal is only visible from the front or face of the mosaic. . . . . In the case of a plain gold or silver background, no modification of the method is necessary, as the worker, by long experience, knows exactly the effect which is being produced on the face of the mosaic. When, however, a background is to be composed of various shades of gold, or gold and silver—a treatment requiring the exercise of great skill and judgment—it is constructed face *upwards*, so that the workers may see the effect of each tesseræ as it is laid; then paper

is pasted *over* it, and it is ready to be packed. . . . . The artist who controls the studio is in constant touch with all the workers, and in the course of his frequent visits to each one advises or corrects as he watches the progress of the work. . . . .

"When all the tracings forming the cartoon have been covered with enamel, they are collected and placed in a frame, so that the whole design, now translated into glass, comes before the artist and workers, and is again critically examined in various lights. . . . . When, therefore, they and the

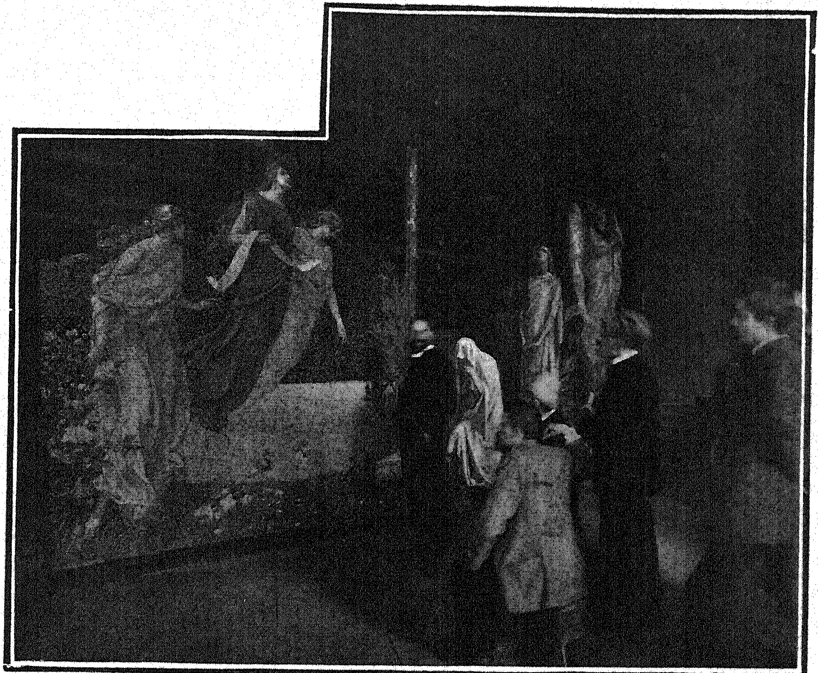


FIG. 231.—Artists and workers examining a mosaic before it leaves the studio.

artist agree that the colours of the mosaic correctly interpret the colours of the cartoon . . . . it is passed, packed, and sent to its destination, ready to be fixed. . . . ."

After dealing in a most practical way with various criticisms of this method, Mr. Hamilton continues:—"When the mosaic is brought to the wall which is destined to receive it, the wall is prepared with cement, and the pieces into which the mosaic has been divided are taken from their cases, and the work of fixing begins.

"If one fixer only is working on a panel, about four feet of mosaic can be placed on the wall at a time. The tesseræ are pressed into the cement, and

after a few minutes the paper is damped off and the mosaic discovered. It is at this stage that the character of the surface is determined. There is no need for hurry while the manipulation of the tesseræ is proceeding, as the cement used does not set firm for some hours after the paper has been removed; and there is no fear of the tesseræ sagging, as they are laid from the *bottom*, and not from the top as in the old method. If, therefore, the designer is also a practical mosaist, and wishes personally to undertake the work of fixing, this method affords him facilities for stamping the work, in its final stage, with his individuality, by giving to the tesseræ with his own hands that 'little push' to which reference has already been made. . . . It must be distinctly understood that the 'face-downwards' method is applicable only to decorative work, and cannot be used . . . . when much delicacy of execution and extreme nicety in gradation of tints are required. In such cases the work is always executed 'face upwards,' and when finished is taken up on to paper from the front." (*Jour. Soc. Arts*, 6th February 1903.)

Marble Mosaic.—The Romans evidently derived the art of mosaic from the Greeks, but it is not by any means equally clear from whence the Greeks derived their initiative. Many plausible explanations are possible, and to a nation so imbued with artistic instincts the promiscuous fragments of white and coloured marbles about their studios could hardly fail to have been suggestive. On the other hand, the associations of the Greeks with Babylonia, Persia, and Egypt, where examples of glass-inlaying and tilework existed, would easily account for its imitation by the Greeks in their beloved marbles, even if marble mosaic had not already been practised in Egypt and India, of which there appears room for a reasonable uncertainty, for in his *Dictionary of Greek and Roman Antiquities*, Dr. W. Smith observes:—"Recent researches into the architecture of Persepolis have, moreover, shown that the bricks in these buildings were made in two tones of colour, and so disposed as to form a literal mosaic pattern. In all probability, then, Greek mosaic was inspired from the East, after the conquests of Alexander. The evidence for this date rests upon the fact that neither in literature nor the monuments can we prove the existence of any mosaic in Greece before this time. The earliest mosaic as yet known is that which decorates the floor of the pronaos of the Temple of Zeno at Olympia, which . . . . cannot be earlier than the first half of the fourth century B.C., and is probably considerably later. . . . . Everything, then, points to the third century B.C. for the introduction of mosaic into Greece. Probably it was never practised to any great extent there; we do not even know whether the Greeks were familiar with the various classes of mosaic which the Romans distinguished from each other." (*Greek and Roman Antiquities*, vol. ii. 3rd ed. p. 397.)

In respect of pictorial effects in mosaic, Dr. Smith apparently gives credence to an Egyptian origin of the art, pointing out that "One of the

finest Pompeian mosaics, signed by Dioscorides of Samos, reproduces a wall-painting found at Pompeii; and the great mosaic at Naples, of the battle of Issus, was probably inspired by the painting by a Græco-Egyptian lady"; and, again, that "The art is further marked by the occurrence of Egyptian landscapes reproduced in ancient mosaics; the finest is the Palestrina mosaic, ascribed to the first century A.D." (*Ibid.*)

But the great period of marble mosaic for pavements undoubtedly was the Roman. The Romans gave different names to the work according to the materials used and the character of the designs; as, for instance, "*litho strotum*," "*opus figulinum*," "*opus sectile*," "*opus tessellatum*," "*opus vermiculatum*," "*opus musivum*"; very much as we now use qualifying terms for different kinds of mosaic. Professor Delamotte has explained that with the Romans, in the "*opus tessellatum*," the tesseræ were small cubes of about $\frac{3}{4}$-inch square, sawn or worked by hand in proper shape and then arranged in geometrical patterns. The same kind of tesseræ was used also in other sorts of mosaic, but it was not called *tessellatum* unless the component parts were exclusively of this square shape. The "*opus sectile*" is so called after the *secta*, or portions cut out from coloured marbles, which in this case were cut into triangles, squares, oblongs, rhomboids, hexagons, etc., and were combined in the floors so as to compose regular geometrical figures. "*Opus figlinum*" differed from the foregoing inasmuch as this work was of a species of encaustic tile or terracotta, and, according to Pliny, was invented about B.C. 24. "*Opus vermiculatum*" was formed of tesseræ of irregular shapes and sizes varying from $\frac{1}{2}$-inch to $\frac{1}{20}$-inch, the pieces being individually adapted to their position, so that they might follow the lines of the design; and thus in the background, or in large spaces of even colouring, these divisions caused an appearance like a mass of worms wriggling, hence the name *vermiculatum*, from *vermes* (a worm). (*Cassell's Technical Educator*, vol. iii.) Of the term "*opus musivum*" Dr. Smith states that this does not appear until late, and its derivation is unknown.

Numerous examples of Roman mosaics have been cited and illustrated in a preceding chapter, and need not be repeated. It may be well, however, to note that although the Romans used marbles and kindred minerals mostly, they also made very considerable use of red-tile tesseræ, particularly for borders and corridors; hence, correctly speaking, their pavements are generally composite mosaics of both marble and ceramic substances, not purely marble mosaics.

During the Early Middle Ages Italian artists in mosaic seem to have devoted their attention mostly to pictorial mural work in glass and precious stones, marble mosaic for the time occupying a somewhat subservient status; but in the fourteenth century there began a work in marble, which, though not mosaic of the ordinary tesseræ style, may perhaps with propriety be called

"sectile mosaic," after the Roman *opus sectile*—namely, the pavement of Siena Cathedral.

This great work of art in marble, with one exception—a square of ordinary mosaic which will be observed in the foreground of the illustration, fig. 232, and which is in reality only a modern copy of the original—is referred to as "*pavimento a graffito*." (See *Pavement Masters of Siena*, G. Bell & Sons.)

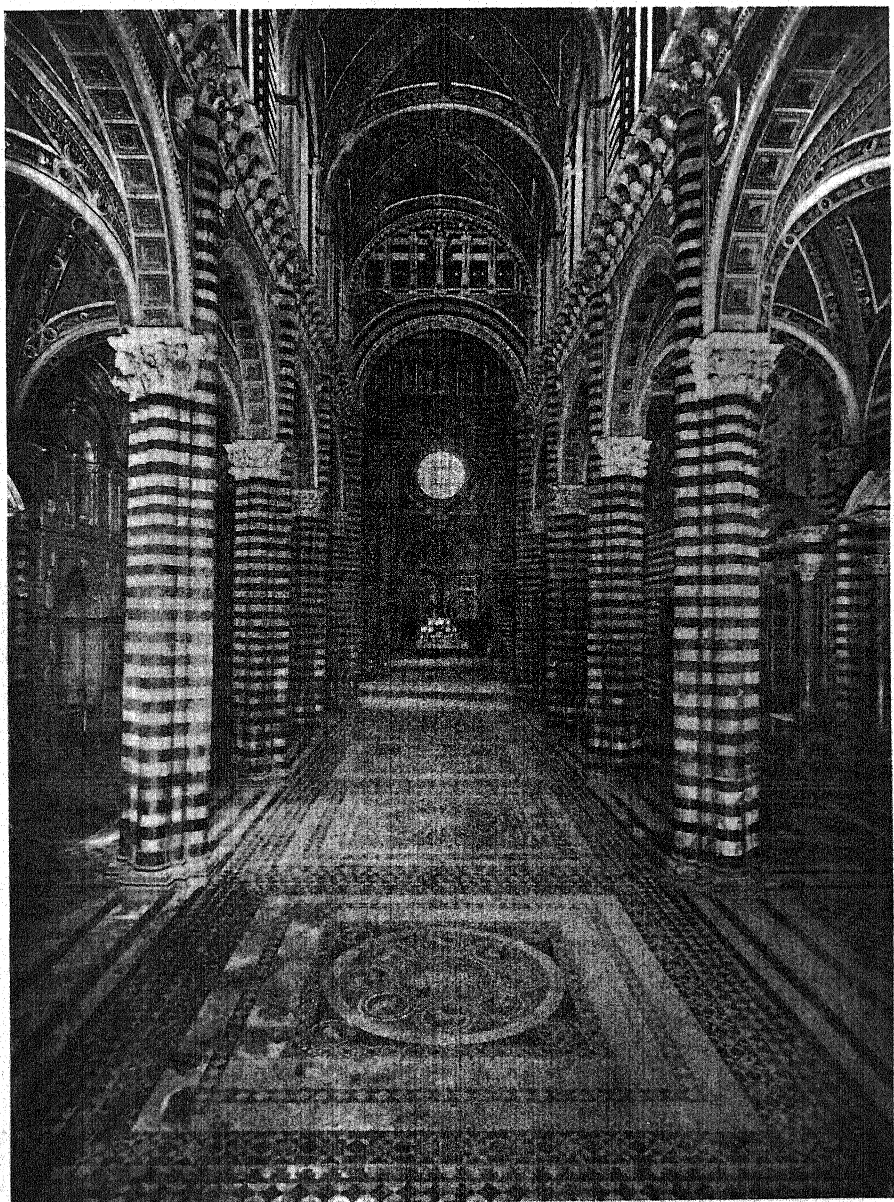
Mr. R. H. Hobart Cust very kindly explains that the pieces of marble are of various sizes, often very large, and are laid together on the principle of puzzle-maps, in irregular segments, yet in strict accordance with design; black marble being used to indicate the field, while the figure or subject is silhouetted against it in white marble. This segmental pavement is known in technical Italian as *commesso* (put together). Details were put upon the white segments or sections, as required, by engraving lines of dots with a trepanning-drill, and the lines were filled up level with hard-setting black stucco, and connected so as to appear one single line, either thick or thin as needed by the design. Yellow, red, and green marbles were sometimes used as adjuncts in the work.

In his history of the pavement of Siena, Mr. Cust shows that Vasari mentioned another example of *commesso* and marble, made at Lucca as early as the thirteenth century. (See *Pavement Masters of Siena*, p. 5, Bell & Sons.)

The Saracens and Mohammadan Turks, who rose in power and extended in empire almost contemporaneously with the decline of Rome, inevitably were brought in contact with examples both of Roman and Byzantine work, and were not slow to avail themselves of mosaic as a means of rendering gorgeous the floors and walls of mosques; even Cordova, where reigned the great Khalif Abd-er-Rahmăn (A.D. 784), although far distant from the centre of Mohammadan influence, furnished a most elaborate example. Stanley Lane-Poole writes:—"The sanctuary was paved with silver and inlaid with rich mosaics." The same author remarks with regard to Egypt under the Mohammadans that "Among the modes of decorating specially honourable parts of the mosque or house, none were more esteemed in Cairo than mosaic-work. . . . . The tomb-mosque of El-Ghōry, built 1503, has a niche inlaid with blue, yellow, and red marbles, in zigzag stripes; while the double dado on either side of it, running the whole width of the south-east wall in two lines, one high up, the other low, is of red, yellow, and black marbles, arranged in square or oblong panels."

Of the Mosque of Kāït Bey, another Mamlūk sultan, and the prince of Cairo builders, he writes:—"Marble inlay covers the lower portion of the walls, and marble slabs are arranged in the pavement. The whole interior surfaces wear the aspect of a beautifully woven and embroidered carpet." (*The Art of the Saracens in Egypt.*)

India, too, furnishes remarkable specimens of marble mosaic. At the sacred



Lombardi.] [*Photo.*

FIG. 232.—Siena Cathedral, Italy.

city of the Sikhs—Amritsar—the one great sight is the Golden Temple; it is of white marble, with a roof of copper-plates richly gilt, and doors of solid silver. The windows are golden, and all along the broad roadway leading up to the temple are golden balustrades and lamps. In the marble flooring of this temple it is said there is much mosaic-work, and that in some respects the temple resembles the Alhambra at Granada. (*Indian Pictures*, p. 171, R.T.S.)

Sir C. Purdon Clarke, C.I.E., who has had considerable experience of Indian handicrafts, greatly praises the work of Amritsar artisans in copper. (*Jour. Soc. Arts*, 18th April 1890, p. 517.)

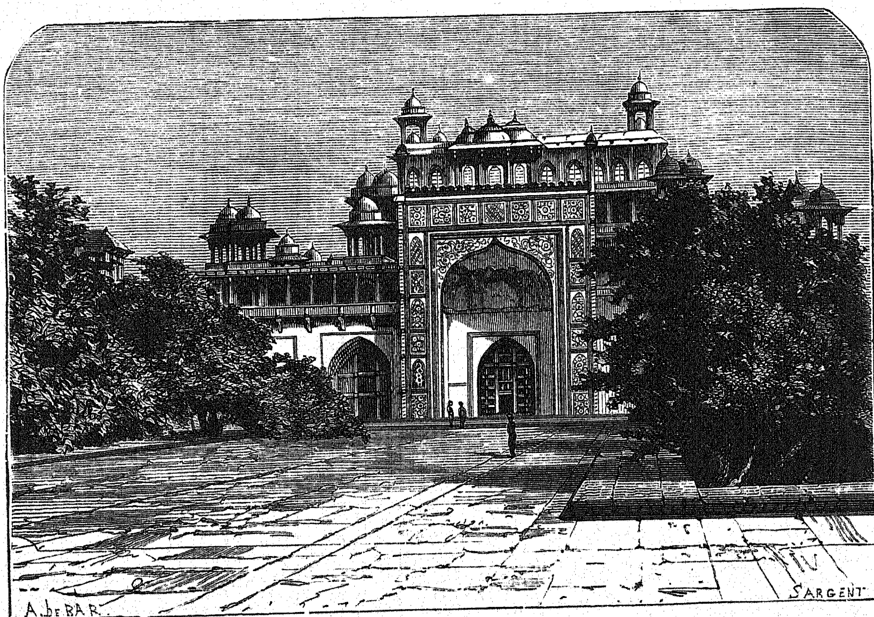


FIG. 233.—Akbar's Mausoleum at Secundra. (*By permission of Cassell & Co.*)

A much finer Indian example of marble mosaic is the tomb of Îtimâd-ud-Daulah at Agra, a monument erected by Îtimâd-ud-Daulah's daughter, wife of the Emperor Jahângîr, to the memory of her father.

Mr. Edmund W. Smith, in his work on the *Moghul Colour Decoration of Agra*, gives several lovely photogravure views of this, both of exterior and interior, including details of some of the marble inlaid work. By permission of the Government of the United Provinces we are able to reproduce one of the plates (Plate XXXI.).

Referring to this subject, Sir George Birdwood, K.C.I.E., writes:—"The revival of mosaic-work in India under the Mo(u)gul emperors was due, partly, to still surviving Saracenic influences, but chiefly to the influence of the Italian

INDIAN MARBLE MOSAIC.

Agra: Itimad-ud-Daulah's tomb.
View of turrets at the corner of tomb.

(From E. W. Smith's *Moghul Colour Decoration of Agra*, pl. lxx. *By permission of the Government of the United Provinces.*)

artists who, during their magnificent reigns, were attracted to India. The Italians of the Renaissance developed two forms of mosaic, the mosaic of the modern Romans (the '*opus minus vermiculatum*' of the ancient Romans), and the mosaic of the modern Florentines (the '*pavimentum scalpturatum*' of the ancient Romans). It was the latter mosaic in *pietra-dura* that the Italians used in the decoration of the Taj at Agra, and which has ever since survived there as a local art, with a character of its own, at once racy of the soil and of high artistic merit." (*Jour. Soc. Arts*, 1st March 1901, p. 267.)

The wonderful Taj at Agra, now in silent desertion, is spoken of as a casket, yet withal a great building; it was this example that drew from Bishop Heber the remark, "The Saracens built like Titans and finished like jewellers." (*Ind. Pict.*, p. 151, R.T.S.)

In Europe, during recent years, a revival of the use of marble mosaic for pavements has been in progress, done mostly by Italians, of whom it is said that in Great Britain alone there are no fewer than two thousand now employed. One of the principal firms engaged in this branch of art is the *Art Pavement and Decorations Co., Ltd.*, by whose courtesy some very interesting facts and photographs were allowed to be made public in the *Royal Magazine* (October 1901). From this source, by permission, the following abridged notes have been derived :—

Only within the last thirty years has mosaic again come into general use in England, yet now it can claim to be one of the largest industries of the artistic paving trade. It is essentially an Italian occupation, and the swarthy denizens of the Sunny South hold a monopoly of it. This is ascribed to the fact that they are said to possess more patience than we Britons. English girls, however, are employed for the simpler stages of the work, and exhibit much aptitude.

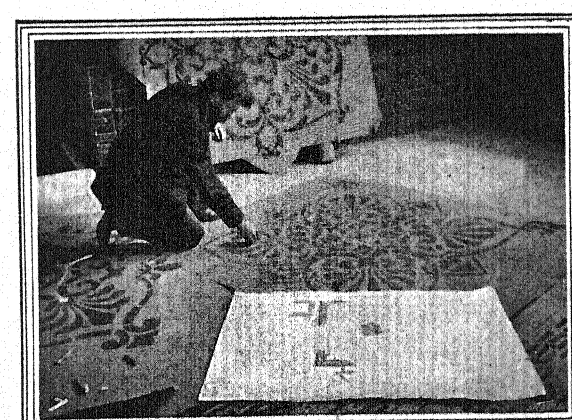


FIG. 234.—The first process: a full-size design drawing.

The coloured marbles are obtained from quarries in many different countries; thus, white and reds from Italy, black and brown from Belgium, green from Ireland, cream from France, and so on. The architect supplies the plan and directions as to design, by means of which a draughtsman prepares his drawing to scale, showing the position of each "tessera."

The drawing is transferred to brown paper, which is cut up into convenient sections, upon which various workmen and girls affix the coloured marbles by means of special gum. An idea of the demand on their patience may be formed from the fact that in 3 feet length of 1 foot wide border some six hundred separate cubes have to be attached in correct position on the brown-paper full-sized plan. Imagine, then, what it is to prepare the floor for large public buildings, such as the new Admiralty buildings, where some 10,000 square yards are laid; the Royal Albert Hall, with its 1500 square yards; the Royal Alexandra Hospital at Rhyl, 2500 square yards; and St. Thomas' Hospital, 5000 yards.

Fig. 235.—A stock of the stone cubes used in the work.

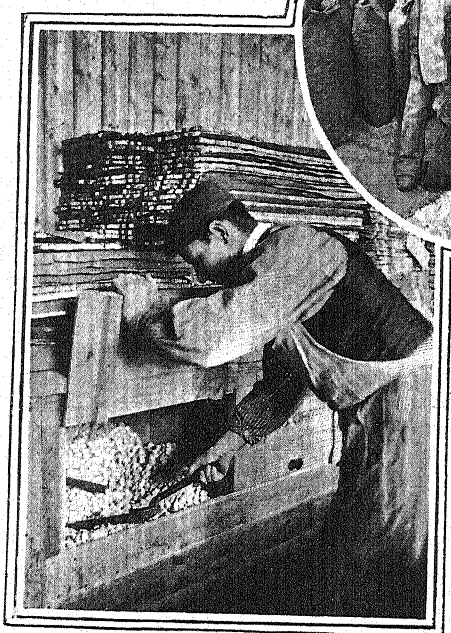


Fig. 236.—The cut stone stored in lockers.

For the paving of one of the largest blocks of offices ever erected in London (Salisbury House), of which the borders alone measure nearly a mile in length, over thirty million pieces of marble have to go through the hands of the workmen, the weight being one hundred and fifty tons.

When the cubes are gummed on to the paper they are placed face downwards, and on completion of the design each section is placed on a rack to dry.

When all are ready, the parts are taken to the building for which they have been prepared, and there placed in their proper order upon the foundation floor already made for them.

Some ten thousand tons of marble tesseræ are annually imported into England, and this increased demand has caused the introduction of cutting machinery and various labour-saving apparatus, which has so reduced the cost that it can now be laid down for but a few shillings per square yard. And yet, such is the quality of the work that it is a customary thing to give a twenty-five years' warranty.

Considerable space is needed for conducting this art on a large scale, and the premises of the aforenamed firm of mosaic-workers are very extensive, and a large staff of workers is employed. (See *Royal Magazine*, October 1901.)

Ceramic Mosaic.—Probably the earliest example of ceramic mosaic is the yellow terracotta cone ornamentation of Warka, Chaldæa. Then come certain portions of the Tell el Yehûdiyeh tilework, and kindred work in Babylon and Susa.

The red-tile tesseræ of the Romans follows; and later still the enamelled-tile mural sectile-mosaics of Mohammadan countries about the twelfth to the sixteenth centuries; while Catalonia seems to fur-

FIG. 237.—Making and mounting the design.

FIG. 238.—Moving the work, when finished, on a tray.

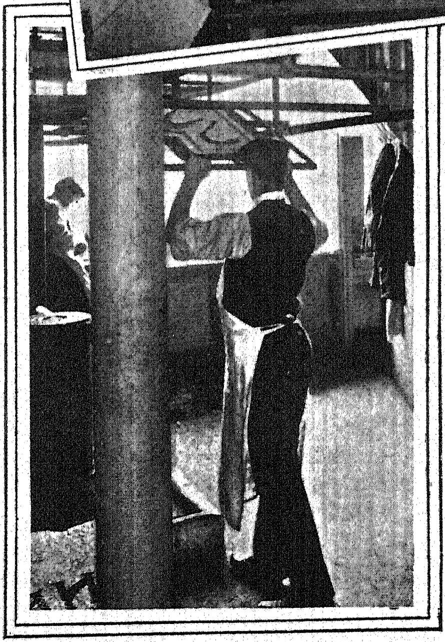


FIG. 239.—Putting the finished work to dry on rack.

nish a connecting-link in the use of mosaic from the time of the Moors onward.

But to England and to the nineteenth century must be awarded the honour of the manufacture and use of ceramic mosaic in its most perfect, elaborate, and useful form.

From Spon's *Encyclopedia of Manufactures* it appears that Singer, of Vauxhall, assisted by a person named Pether, about 1839, made ceramic tesseræ from plastic ceramic compositions. "Singer's process was to place clay, well-kneaded and of various colours, and as near as practicable of uniform stiffness, in a machine where, by means of levers, it was subjected to pressure and made to exude from an aperture 6 inches by ½-inch; as it protruded it was cut into lengths of 3 inches, and these small pieces were left some days to dry. Fifteen or more were then laid upon one another, and a frame of corresponding size (across which were strained wires crossing one another at regular intervals), sliding vertically on two uprights, was made to pass through them, cutting out by this motion one hundred or more tesseræ. . . . . The tesseræ were then burnt and put together on slabs of slate. The great hall of the Reform Club was executed by Singer with tesseræ thus made and ground down to a true surface. He also made a pavement for the court of the present Royal Exchange of similar tesseræ; but, being laid down during winter, the cement gave way, and the whole was taken up and removed." (Spon's *Encyclopedia of Manufactures.*)

In 1841 A.D. Blashfield, another early experimenter who had already tried numerous compositions of cement, plaster, painted tiles, and so forth, and for whom Messrs. Copeland, of Stoke-on-Trent, had made red and black encaustic tiles (see Spon's *Encyclopedia*), happened to see porcelain buttons made at Minton's works by means of the clay-dust pressing-machines, invented by Prosser, of Birmingham, and it occurred to Blashfield that this new process could be utilized for the manufacture of tesseræ.

Subsequently the late Mr. Herbert Minton made experiments, and sent some 1-inch cubes to Blashfield, the cubes having a white body with a blue-coloured face. The latter is said to have crazed and cracked, but Minton eventually succeeded in producing good blue-and-white tesseræ. With these Blashfield formed a test-slab of mosaic, backed by cement and tiles; and this first piece of Minton's mosaic-work was exposed to weather for a whole winter, and successfully bore the test.

Then Prosser made more machines, and Minton pushed the manufacture of tesseræ and tiles; eminent artists and architects became interested; and in 1848 Sir Digby Wyatt published a book on the subject of mosaic, and gave considerable help to manufacturers who were attempting to introduce ceramic mosaic.

In an interesting paper on mosaic, read at the Society of Arts recently by W. L. H. Hamilton, Esq., of the Venice and Murano Glass Co., he states

that "On the announcement of the intended exhibition of 1862, Messrs. Maw & Co. decided to move a step in advance of what had hitherto been done, and to produce a pictorial pavement in several colours. They therefore commissioned Sir Digby Wyatt to design a pavement of that character for them, which they executed in tesseræ of nearly a hundred different tints made by themselves; and, as Sir Digby Wyatt states, this was the first practical effort to revive pictorial mosaic amongst us. Such was the position of the mosaic art in England in 1862. It shows that a certain interest in the art had been created, and this interest was stimulated by Sir Digby Wyatt, who in that year read a valuable and most interesting paper before the Royal Institute of British Architects on 'Pictorial Mosaics as an Architectural Embellishment.'" (*Jour. Soc. Arts*, 6th February 1903, p. 232.)

But for some reason small tesseræ seem to have been comparatively neglected, and geometrical tessellated floors, with or without figured encaustic tiles, preferred for many years. During the last twenty years, however, fashion veered in the direction of marble mosaic pavements; and as these became more and more extensively used, ceramists followed suit and devoted greater attention to ceramic mosaic. So effectively has this been done, that Mr. W. Burton, F.C.S., at the Society of Arts on 4th Feburary 1903, was able to assure the audience that "As a matter of fact there was a good deal more mosaic made in England to-day than in Venice, and a great many more men were employed here than in Italy. The people of England were really the first to revive mosaic, not the Venetians." (*Jour. Soc. Arts*, 6th February 1903, p. 244.)

As to the *technique* of ceramic mosaic, the nature of the bodies and the mode of manufacture of the tesseræ have already been described in Chapter VII. The composition, degree of vitrescence, and cost of such tesseræ depend very much upon the particular colours forming the pattern; some are of simple unmixed clays, not particularly expensive; while others—such as vitreous blue tesseræ—may contain an appreciable proportion of costly oxide of cobalt, etc. White, blue, pink, and green ceramic tesseræ will usually be impervious; on the other hand, red, chocolate, and some shades of buff tesseræ may be only semi-vitreous, or, occasionally, even porous.

Tesseræ for mural work may be glazed, gilt, or lustred, if brilliancy of surface and of colour are required.

In other respects the designing, drawing, fixing, etc., are governed by general principles similar to those controlling the manufacture of glass and marble mosaic-work already described. Ceramic mosaic undeniably possesses certain advantages over glass or marble for pavements, and forms a serviceable alternative to glass mosaic for mural decoration. Its durability, colour possibilities, imperviousness, and consequent facility in cleansing, are not to be overlooked when making comparisons.

In making a ceramic mosaic floor, as a rule, larger tesseræ are used than for mural pictorial mosaics, and greater simplicity of design is more appropriate. Sir W. B. Richmond has said, "Severity was the mother of mosaic, simplicity its father"; and again he has said, "He made a great many mistakes at St. Paul's, but never made the mistake of being too simple." (*Builder*, 14th March 1903.)

But to continue the technique of ceramic mosaic: the design of the whole floor having been first set out to a scale of either 1 inch or 1½ inch to the foot, a tracing should be made and reversed. A full-sized drawing is then made from the reversed tracing, upon tough paper or thin cardboard, cut into

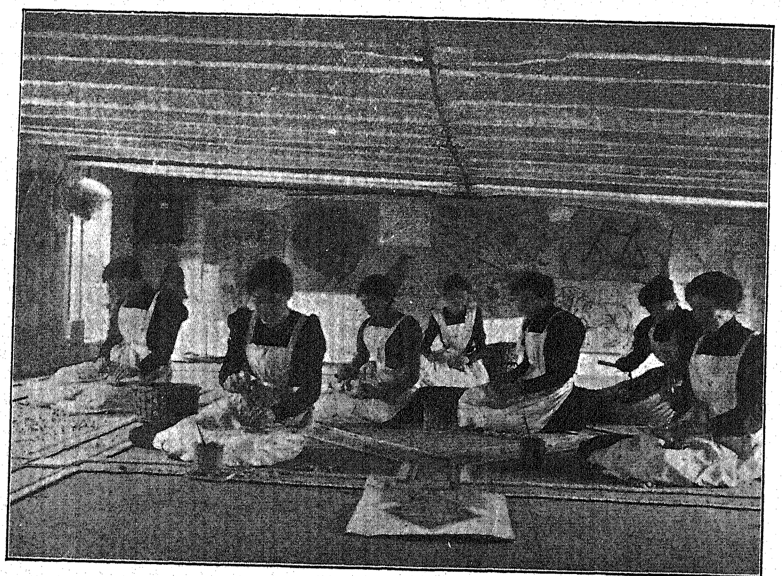


FIG. 240.—Working a ceramic mosaic pattern. (P. 10 of Carter & Co.'s *Interesting Notes on Ornamental Tile Manufacture.*)

sections of convenient working sizes; the positions of the tesseræ being indicated, and the tones of colour suggested in their respective places, either by colour or by numbers, marks, or letters signifying colour. The tesseræ are then gummed into their proper positions, face downward, on the paper; when this is done, the completed sections are allowed to harden, each section bearing a number corresponding to that shown on the fixing-drawing or floor-plan. This is a drawing made to scale, with the sections of mosaic indicated and numbered for the fixer's guidance (see Chapter XV.).

In some cases it is not necessary to reverse the drawings, for when a space is symmetrical, and the design also, no difference would be made by tracing and reversing; hence in such instances the full-size drawings may be

made directly from the scale drawing. But all irregular spaces and lettering, and many left and right hand figures, must be reversed. In some cases, when the drawing is already full-size, a tracing may be made the right way, and then simply gummed the reverse way on to the mosaic paper, and the tesseræ fixed on this.

The foundations of the building where the floor is to be laid having been prepared as for an ordinary geometrical or encaustic-tiled floor, and spread with a level coating of freshly prepared cement, the sections of ceramic mosaic are placed in their positions according to the numbers on the fixing-plan, paper uppermost. The whole is then swilled with water, and the paper on softening is lifted off the tesseræ faces and removed. The tesseræ are then very carefully examined, and any corrections or making good defects which are seen to be necessary should be made before the cement sets or hardens.

The mosaic-fixers, by an arrangement of planks—which must not under any circumstances touch the face of the newly laid floor—now begin to go all over the floor with batters, beating the mosaic perfectly level, and testing it with a true straight-edge.

Unless this is carried out efficiently, and all little projections removed by replacing the tesseræ so affected, or knocking the projecting ones into the cement, the floor will always suffer from such lack of good workmanship. For tesseræ which project, upon beginning to wear, will immediately kick up, and a vent made in this manner is sufficient to affect the whole floor, owing to the difficulty of replacing without loosening others.

This being done, the floor surface is then grouted with cement cream—which may be of a special composition—and the surface subsequently cleaned with sawdust, and with water and flannels.

Ceramic mosaists—or shall we say "museaists"?—may with advantage take a hint from Mr. A. Lys Baldry. He writes:—"Some judgment on the part of the workpeople engaged is necessary, for they have to follow closely the variations of colour in the cartoon, and they must understand how to space the tesseræ so as to hit the mean between excessive roughness and irregularity of execution, and that mechanical precision which would make the picture when finished hard and lifeless." And although he comments upon and fully comprehends its limitations, he still says:—"It satisfies to a remarkable extent most of the conditions which must be observed by the decorator, and . . . . fits particularly well into an architectural scheme." (*Modern Mural Decoration*, p. 48, Newnes.)

Sir W. B. Richmond's experiences with his historical work in St. Paul's Cathedral also find a modest counterpart in the experiences of manufacturers of ceramic mosaic. The effect of a design in a studio may not always prove equally satisfactory when it comes to take its place in a building among totally different surroundings. In his paper read before the Society of Arts,

June 1895, Sir W. B. Richmond, along with many other excellent things, said :—"As I see my work now completed in mosaics I see reasons for certain regrets. . . . . I also made too many details ; in point of fact, in a sense, I put in more work than was really needed. . . . . Every portion of a building requires different treatment, owing, of course, to the manifold effects of light to which surfaces are subjected. . . . . Pure white I found to spread excessively, dark blue to tell as black, amber colour to become quite unreasonably dark, pale cool pinks even greyed very much at a distance, and required to be outlined with a strong red to give their value. . . . . White lines in light green are very disastrous, except at rare intervals ; either a toned grey or a dull yellow breaks the green best. . . . .

"To start with, I thought a palette of thirty colours, or rather shades of colour, was sufficient, and there I was right; that number is much more than sufficient. As my experience increases, eight or ten tones of colour are ample. . . . .

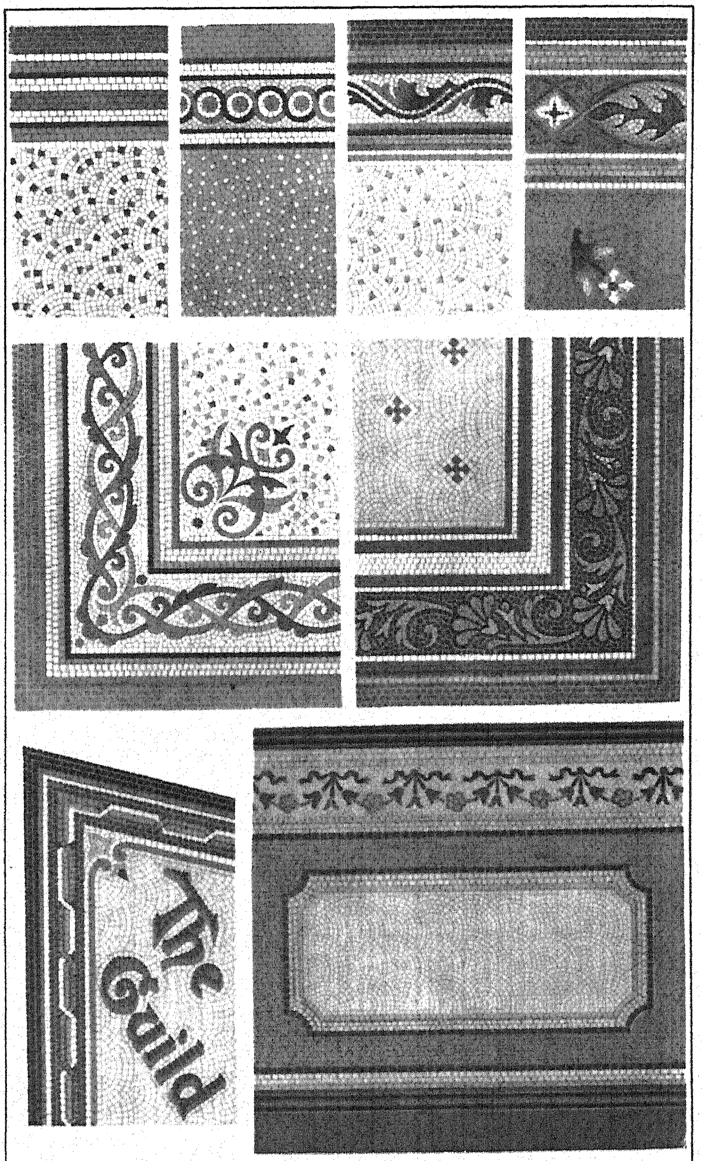
"One need never be afraid of letting the ground show the $\frac{1}{16}$ or even $\frac{1}{4}$ of an inch in width round each cube. I would even go so far under certain circumstances of light to expand even that width. . . . . I take it that we all learn more by our own mistakes than by what success we may now and then attain." (*Jour. Soc. Arts*, 21st June 1895.)

Again, Mr. Walter Crane has said :—"In most cases the mosaics which were most decorative were perhaps least pictorial," etc., etc. (*Journal R.I.B.A.*, 23rd March 1901.)

Other considerations are emphasized by Mr. J. D. Crace, President of the Incorporated Institute of British Decorators. In his presidential address on 7th June 1900, he remarks :—"Mosaic is the most magnificent and the most completely decorative of all the forms of coloured decoration. . . . . Its best effects are obtained on curved surfaces, or if on plane surfaces, then on such as are not framed in by mouldings, but are rounded off at the openings or external angles. Its great charm lies in the mysterious play of light on large expanses of curved or slightly rounded surface, where the metallic character of the gold is subdued or softened down sufficiently to modify the abrupt transition from metal to colour. . . . . It is quite possible to use mosaic for external ornamentation. But it requires at least as much care without as within, or it may easily fail to assimilate with its surroundings. . . . . Nothing could be more blindly inappropriate than the use so often made of it in this country during the last thirty years ; I mean sticking bits of it, a foot or two wide, into the sunk panels of a reredos level with the eye and on a rigidly flat ground. . . . . Great simplicity of treatment and extreme care in outline are among the first necessities in mosaic-work, and only very simple forms and colouring should be used in the borders." (*The Coloured Decoration of Architecture*, p. 6, Painters' Hall.)

EXAMPLES OF CERAMIC MOSAIC.

PL. XXXII.



ANDRE & SLEIGH, LTD., BUSHEY, HERTS.

Selected from Messrs. Maw & Co's
illustrated designs, by permission.

Similarly, regarding joints in mosaic-work, Halsey Ricardo remarks:—"To keep the tesseræ equal and to set them all to one level face is to renounce the great quality of life in one's work, and to throw away much that constitutes the charm of the material." (*Jour. Soc. Arts*, 21st January 1902.)

To attain pleasing and satisfying effects in ceramic mosaic pavements it is not always essential to have angular or rectangular tesseræ. The vestibule of the City of Birmingham Museum and Art Gallery is a case in point. There a most pleasing floor is made up of tesseræ having apparently an oval or oolitic section, showing comparatively wide spaces of cement or mastic; the latter having the dark translucent shade of flint, contrasting beautifully with the greys and pinks of the tesseræ, and resulting in a simple mosaic, pleasing and unobtrusive to a degree.

The agreeable foothold afforded by mosaic floors renders them particularly useful and appropriate for many ecclesiastical, public, and private buildings; their cleanliness, durability, absence of gloss, possibilities of gorgeousness, their antique and venerable character, absence of decay, of odour, and of noise, are undeniable advantages; and given a good foundation, good cement or mastic, good laying, and reasonable protection from the elements, a ceramic mosaic floor would appear to be well-nigh everlasting, and ever beautiful.

CHAPTER IX.

COMPOSITION OF GLAZING TILE-BODIES.

CONTENTS.—Interchange—Crazing—Defects of dust-made tiles—Insanitation—Qualities of a good glazing tile-body—Preparation of bodies—Shrinkage—Tile-pressing—Embossed tiles—Placing—Burning—Recipes.

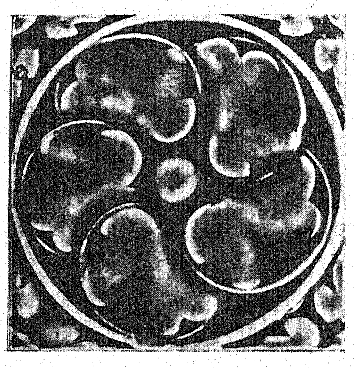


FIG. 241.—Intaglio tile, leadless glazed.

IN certain instances glazing tile-bodies are interchangeable with flooring tile-bodies, when a difference is made in the firing; but by far the greater portion of white, cream, and ivory tinted bodies are not adaptable to such interchange, and, as these form the bulk of the output of glazed tiles, it becomes necessary to prepare special bodies.

Hence it is not always disadvantageous to separate these departments of the industry — unglazed tiles and glazed tiles; and in actual practice this is frequently done, some firms devoting themselves entirely to one branch and some to the other.

In the formulation of recipes for glazing tile-bodies, when the tiles are to be made from dust-clay, as is customary now, several special considerations must be kept in view, such as exactness of size, rigidity of form, preciseness and uniformity of tint, the quality of withstanding rapid heating and cooling in glost kilns, economical cost, disposition to loss in process of manufacture, and suitability to the glazes in respect of crazing, pinholing, peeling, and smoothness of surface; for, however paradoxical it may appear to say that glazes by no means exercise paramount influence in the matter of crazing, or even of glossiness, it is undoubtedly a fact, for badly constituted bodies will cause the best of glazes to craze, and under certain conditions to become partially "eggshell" or vesicular of surface.

The importance of this subject of crazing is well known to everyone who

has, even in the most cursory manner, observed the instances of defacement and discoloration of glazed tilework. In a paper read before the Society of Arts on 21st January 1902, Halsey Ricardo said :—"The question of using tile externally is made very difficult by the doubtful behaviour of the tiles themselves. It is a common sight to mark great patches on walls, where the tiles have been and have dropped off—to find them cracked and discoloured. The Underground Railway here is painfully rich in examples."

And in the *Pottery Gazette* for August 1900 (p. 921) reference is made to the "frequence of crazing observed in decorative panels and architectural pieces."

When the extensive use of glazed tiles for the construction and decoration of hotels, hospitals, baths, asylums, shops, restaurants, dairies, and many other public and private buildings, is considered, along with the far-reaching possibilities of such tilework for maintaining or prejudicing the health of vast numbers of persons, it obviously behoves all concerned in building construction and sanitation to ask with all gravity whether glazed tilework merits the confidence reposed in its hygienic qualities.

If it is desirable that a drain-pipe, for example, should be an efficient appliance, regardless of the thin gloss upon its surface, so is it desirable that, as far as practicable, a glazed tile should be. And if it is necessary to examine and test the one, why should not the other, for many purposes, also be examined? For whether practicable and convenient or not, it is quite plain that until either crazing is made to cease or glazed tile-bodies rendered impervious—no matter how richly designed and coloured—glazed tilework or faience may yet fail to fulfil hygienic requirements.

Some have supposed and assumed that a reversion to plastic methods of manufacture will correct this defect, but there is abundant evidence to the contrary in the crazing of large quantities of plastic-made lead-glazed wares. It may thus be demonstrated that the dust-clay tilemaking process is not alone to blame, and that its desertion will not necessarily solve the problem.

The dust process undoubtedly imparts a more or less granular condition or texture. In the case of floor-tiles this is largely negatived by agglutination arising from semi-vitrescence; but in the case of glazing tiles, which, to facilitate glazing by immersion, must be receptive after the first burning, the absence of any considerable degree of agglutination during burning leaves the granular condition strongly in evidence. When, in addition, an *excessive* proportion of china-clay is used either to induce porosity, or for economical reasons, then the weaknesses of the tile speedily become appreciable. Crazing and frost-shivering under such conditions are rarely absent; for china-clay possesses almost insuperable tendencies towards crazing when employed in excess in easily burned earthenware bodies. And although its behaviour in brick-enamels under felspathic glazes is excellent, it is a rare experience to

see a specimen of pure china-clay (kaolin), to which ordinary earthenware glaze has been applied, neither crazed nor shivered. Lead glazes do not prevent this; for notwithstanding the hundred and thirty years' *régime* of plumbum in British ceramics, every householder knows what crazed ware is.

Reach down a crazed dinner-plate that has been in use, warm it, and then observe the odour it evolves; then ask if yet more sponge-like crazed tiles, subjected for years to humid emanations in a congested apartment in our moist British climate, are likely to be reliable hygienic appliances.

But the problem of their elimination seems almost hopeless to individual effort working under fiercely competitive conditions; yet something must be done if public confidence is to be retained.

There is abundant evidence that the composition and preparation of the bodies exercise a transcendent influence for better or for worse in glazed tiles. As with plumbic glazes, so with non-plumbic glazes, you may apply half a dozen different glazes to one body, and they may every one craze without exception; and you may apply identically the same half-dozen glazes to another body, and those very glazes shall, every one without exception, be sound, the two series being burnt in the same kiln. It is so with bodies made in England, and precisely so with bodies made in France. It is so also with native marls unmixed with other ingredients; two different cane marls may be glazed with the same glaze and burnt in the same kiln, and one may craze invariably and the other almost invariably be sound.

All this, quite apart from influences arising from slip-casting, plastic-pressing, and dust-pressing, thin-dipping, thick-dipping, easy firing, and the like. There are, of course, ingredients that tend very much to induce crazing when associated in the glazes, but the above defects are observable when all these considerations have been carefully attended to. The most trustworthy of glazes may be disastrously affected by inferior bodies.

Summarizing, then, results of experiment and observation show that:—

(1) Vitreous bodies when glazed are as likely to craze the glazes as porous bodies.

(2) Shrinkage of a clay during burning is not of itself a criterion of crazing tendencies.

(3) Compositions containing barytes have strong tendencies towards crazing the glazes.

(4) Burnt kaolin induces porosity, and may induce crazing of the glazes and shivering of the body.

(5) Fine plastic ball-clays often evince less tendency towards crazing than china-clay, and less porosity.

(6) Certain finely siliceous ball-clays, certain cane marls, and certain red-burning clays are remarkably free from disposition to craze.

(7) The addition of finely ground calcined flint to an earthenware body, which otherwise crazes, will often, though not always, correct the defect.

(8) In hard porcelain bodies the addition of lime is advocated as an antidote to crazing, but this addition does not effect the same result in white earthenware bodies.

(9) Compositions such as (*a*) $3\frac{3}{4}$ lbs. dry plastic ball-clay, $1\frac{3}{4}$ lbs. dry china-clay, $\frac{3}{4}$-lb. dry flint, $\frac{1}{4}$-lb. dry stone; (*b*) 3 lbs. dry plastic ball-clay, 6 lbs. dry china-clay, 2 lbs. dry flint, $\frac{1}{4}$-lb. dry stone, usually appear liable to crazing.

(10) Compositions such as (*c*) 5 lbs. dry plastic ball-clay, 5 lbs. dry china-clay, 10 lbs. dry flint, 5 lbs. dry stone; (*d*) 5 lbs. dry plastic ball-clay, 6 lbs. dry china-clay, $8\frac{1}{2}$ lbs. dry flint, $2\frac{1}{2}$ lbs. dry stone; (*e*) 4 lbs. plastic ball-clay, 4 lbs. flint, usually carry glazes of the ordinary white earthenware type very satisfactorily, providing treatment and firing are suitable.

(11) An excessively siliceous body will not glaze satisfactorily because of its liability to "peel" or shell off the glazes.

(12) An excessively siliceous body will not receive prints of underglaze colours satisfactorily.

These more or less conflicting tendencies have all to be most carefully considered and balanced, and compensations arranged, when formulating glazing tile-bodies. Other observers, no doubt, have met with other experiences, some of general application, others only occurring in their own particular case; these, too, will individually have to be taken into account.

A decorative-tile works manager of long experience advises that where it is desired to manufacture really good sound tiles, the best course is to first of all fix upon a reliable and satisfactory body composition, and then endeavour to adapt everything else to it; that is to say, have the dies made of such dimensions as will provide for the ordinary shrinkage of that formula when properly burned, in the manner and to the temperature experience has proved best.

Then prepare and adapt glazes to suit the body under these conditions, and use only such colours as are possible without altering the conditions.

Preparation of the Bodies.—To avoid reiteration, it may be remarked that the methods described in Chapter VII. for the preparation of floor-tile bodies are in a great measure applicable to the preparation of bodies for glazed tiles and faience, but yet depending partly upon the quality or class of tiles it is intended to make. In the case of tiles of which the glazes are to be dark, such as dark browns, orange, and bronze greens, the bodies may perhaps, without disadvantage, be prepared by the cheaper processes. But in the case of tiles intended to be dipped in light-tinted glazes, and in the case of superior white bath and dairy tiles, the following method is perhaps preferable:—

The ball-clays and china-clays are separately reduced to slip with water,

in two separate blungers, making whatever mixture of several kinds of ball-clays may be desired in the ball-clay blunger, and whatever mixture of several qualities of china-clays is desired in the china-clay blunger; the ground calcined flint and ground Cornish china-stone being received from the mills in a slop state, and placed in suitable tanks ready for use. Each of the slips must be carefully brought to the standard consistency specified in the formula, ascertained by the weight in ounces of a slop pint.

To mix the body, a wooden measuring-staff, called a "gauge-stick," is used, *i.e.*, a notched or nailed lath of about 12 or 14 feet length, the notches or nails indicating the vertical height in the blending tank or ark to which each slip must be allowed to rise, the slips usually following in the order of, first, ball-clay slip at 24 ozs. to pint; secondly, china-clay slip at 26 ozs. to pint; thirdly, slop flint at 32 ozs. to pint; and lastly, slop stone at 32 ozs. to pint.

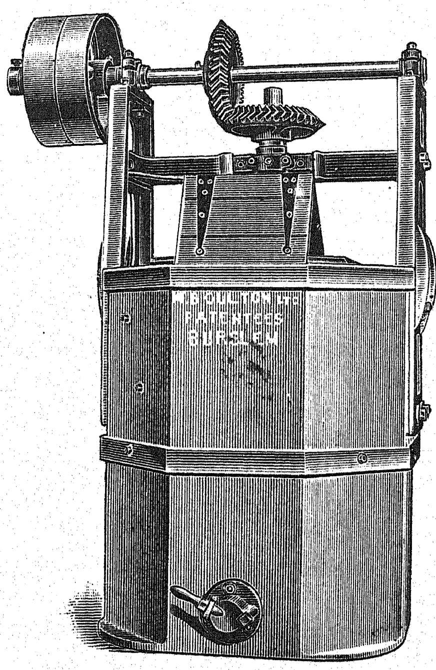


FIG. 242.—Knife blunger. (*By W. Boulton, Limited, Burslem.*)

The blending ark is usually at a relatively low level, so that the several ingredients run in from the blungers by gravitation.

In case of the ball-clay slip, a sieve of 60^h or 80^h mesh may be placed at the outlet of the blunger, so as to refine this before it passes into the blending ark.

When all the slips have been run in, if any stain is specified, this must now be added in a state of finely divided suspension in water; then the mechanical agitator, with which the blending ark must be equipped, should be set at work until the whole mixture is intimately incorporated together into a homogeneous condition of cream-like consistency, but without any frothiness.

After agitation and thorough intermixing of the blending has been effected in such a manner as to avoid the introduction of air-bubbles, the mixture may be pumped up and allowed to flow through a range of magnets fixed in a trough, so as to extract particles of metallic iron. After passing the magnets, the slip must be conducted to a tier of sieves of two or three heights, the sieves used being either 60^h and 90^h or 80^h and 100^h mesh brass-wire sieves, or their equivalents in silk lawns.

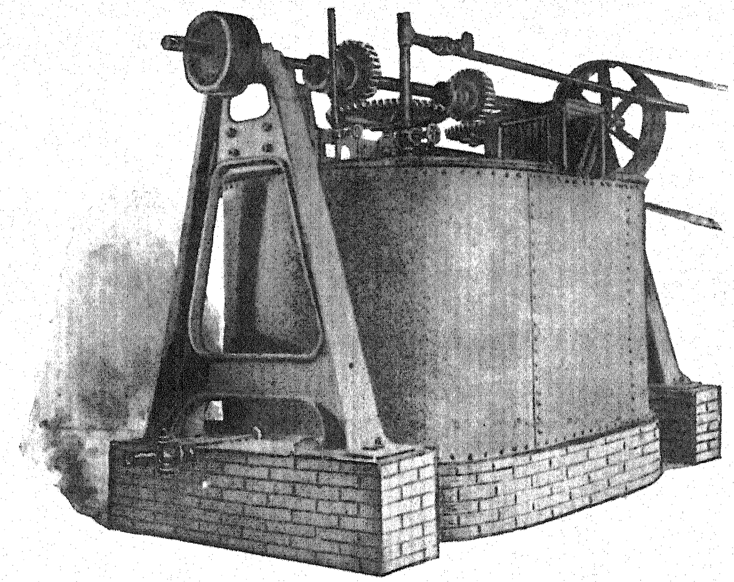


FIG. 242A.—Duplex blunger. (*By the Crossley Manufacturing Co., Trenton, N.J., U.S.A.*)

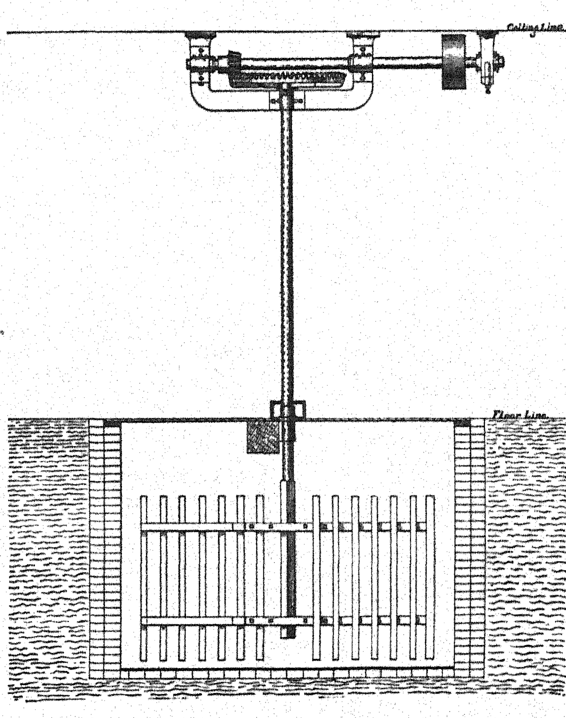


FIG. 242B.—Clay-slip agitator. (*By the Crossley Manufacturing Co., Trenton, N.J., U.S.A.*)

From this apparatus the slip should fall into a store ark or tank, in which a slowly-moving agitator is in constant operation; from this receptacle it may be either pumped upon a drying-floor and dried by heat, or the slip may be pumped into a filter-press, and so formed into plastic clay, which can be subsequently dried and made into dust.

The clay-filter press was invented by W. Needham and James Kite, of London, in 1853 (patents Nos. 1669—1853, and 1288—1856). The illustration (fig. 244) is from a sketch of one of the original presses as exhibited in 1862. Substantially the same press is used now.

White, ivory, and cream tinted bodies may all be passed through the same range of apparatus at separate times, provided that previous to the treatment of each different sort of body all the appliances are thoroughly cleansed.

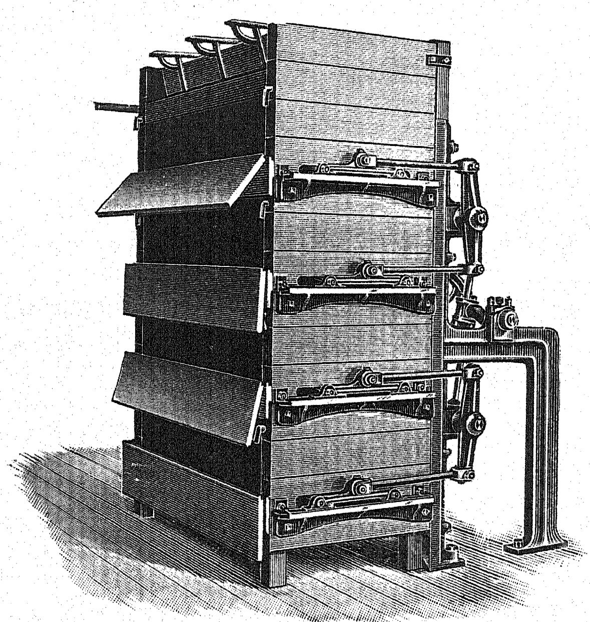


FIG. 243.—Tier of sieves. (*By W. Boulton, Ltd., Burslem.*)

Coloured bodies, whether simple marls or artificially coloured compositions, should be treated in a distinct range of apparatus.

With regard to the standard slop-pint weights of the several slips forming the compounds, it may be asked—Why such great dissimilarity? It is simply this: long experience has demonstrated that at the standard consistencies indicated by the specified pint weights, the individual slips happen to be in the most eligible condition for mixing with each other without too great a tendency to subsidence or sedimentation on the one hand, or to imperfect mixing or streakiness on the other. Thus at 24 ozs. to pint, ball-clay slip, of the type in question, is just of a suitable creamy consistency, and upon drying is found to yield dry substance of about $6\frac{1}{2}$ ozs.; while china-clay slip must be 26 ozs. to slop pint before it attains a similar consistency, and upon drying this yields about $9\frac{1}{2}$ ozs.; whereas ground calcined flint does not attain the requisite creamy condition until it is 32 ozs. to slop pint, with a dry-substance yield of about $19\frac{3}{4}$ ozs. per pint. Ground Cornish china-stone usually attains the

proper consistency at 31 ozs. or $31\frac{1}{2}$ ozs. to pint, but the standard is 32 ozs., because this facilitates commercial dealings with it by bringing it into

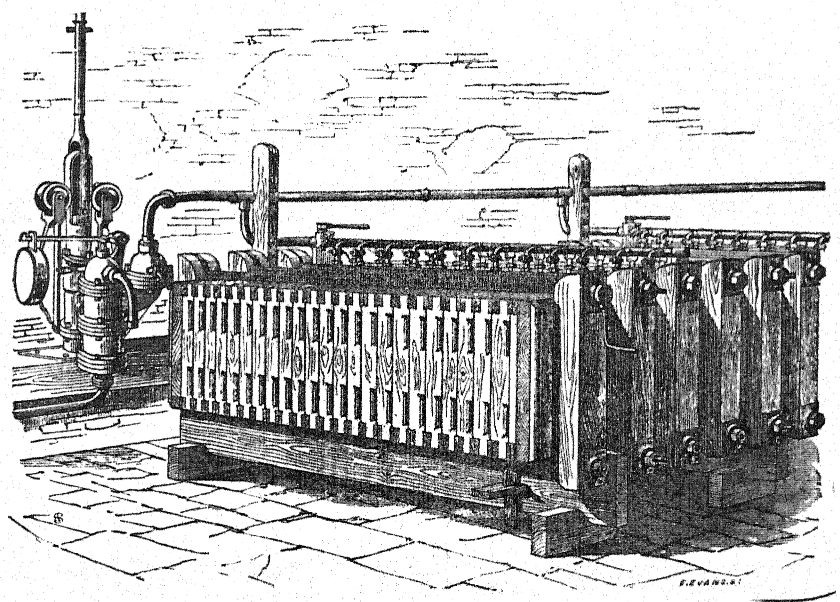


FIG. 244.—"Needham and Kite" clay-press.

uniformity with ground flint slip. The 32-oz. slop pint of Cornish china-stone usually yields about $19\frac{1}{4}$ ozs. dry substance.

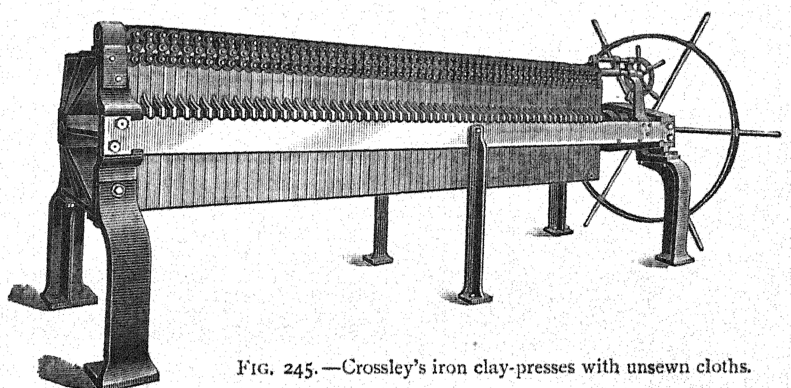


FIG. 245.—Crossley's iron clay-presses with unsewn cloths.

It will thus be seen that the slight difference in the specific gravity of the several ingredients does not control or indicate the relative consistence of the

slips. The real cause of it lays in far more profound physical affinities for water naturally existing, in varying degree, in the ingredients concerned.

Possibly these affinities are connected with the affinity of water for hydrated silicates or hydrated silicic acid ; but to attempt to push the inquiry further would be to trespass unnecessarily upon a purely scientific field of research, which has already been discussed in other works on the suspension and osmose of clays.

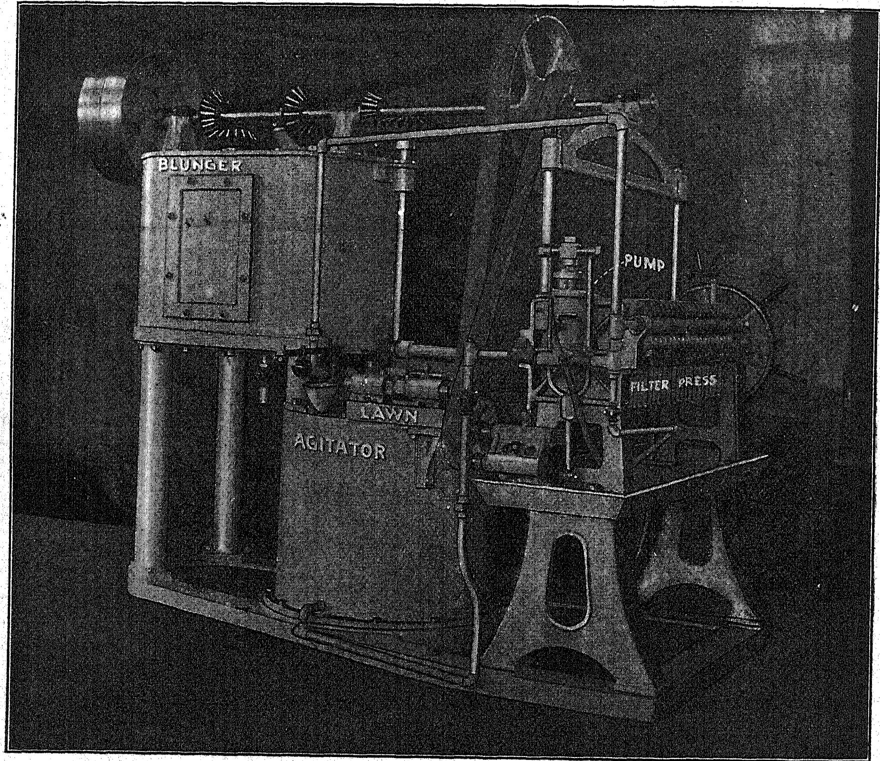


FIG. 246.—Crossley's complete outfit.

Nevertheless, its effect on the practical conduct of a pottery is not by any means ephemeral ; for example, suppose it is desired to convert a formula from a *dry-weighing one* to a *wet-measuring one*, then the phenomenon above mentioned immediately comes into the calculation in a most forcible manner. Suppose the formula to be converted is :—

5	lbs.	of ball-clay	in a dry state.
6	,,	china-clay	,,
$8\frac{1}{2}$	,,	ground flint	,,
$2\frac{1}{2}$	,,	ground stone	,,

Then since the dry contents of a 24-oz. pint of ball-clay slip is only one-third of that of a 32-oz. pint of ground-flint slip, if we take the flint as unity, we must, to convert the formula, first multiply the lbs. weight of ball-clay by 3.

And because the 26-oz. pint of china-clay slip only contains half the dry substance of a 32-oz. pint of flint, then we must multiply the china-clay weight by 2. Hence the following proportionate mixing:—

$5 \times 3 = 15$	inches	ball-clay slip at	24 ozs.	to pint.
$6 \times 2 = 12$	,,	china-clay ,,	26	,,
$8\frac{1}{2} \times 1 = 8\frac{1}{2}$	,,	flint ,,	32	,,
$2\frac{1}{2} \times 1 = 2\frac{1}{2}$	,,	stone ,,	32	,,

That is the simplest mode of making the calculation, and does not take into account the question of hygroscopic moisture in the clays. When, however, the latter is taken into consideration, the conversion of the formulæ by this process will be found practically correct, for although expressed in simple terms it is really founded upon observed facts which a little consideration of the premises will render evident.

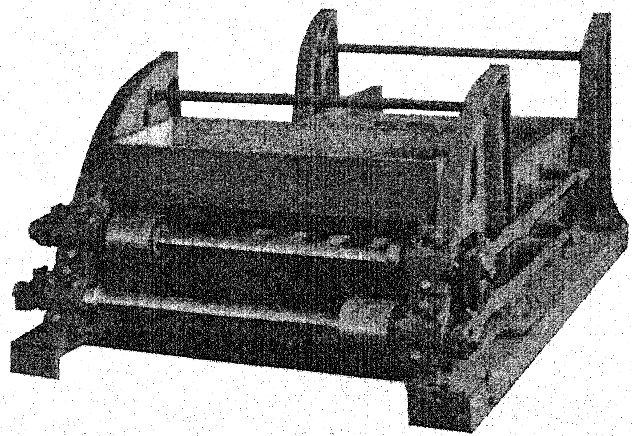


FIG. 247.—Crossley's sifter.

In cases where the slop-pint weights of the formula it is desired to convert do not coincide with the standard pint weights—24, 26, 32, 32—then the reckoning becomes more complex. For example, to convert the following formula from a *slop measure* to a *dry-weighing*—

15	inches	ball-clay slip at	24 ozs.	to pint
9	,,	china-clay ,,	,, 26	,,
6	,,	slop flint	,, 31	,,
4	,,	slop stone	,, $30\frac{1}{2}$	,,

perhaps the best procedure is first to find its equivalent measure at the standard pint weights; it could be done another way, but this is probably the easier.

Let it first be noted that two of the items are already at the standard weight; then coming to the slop flint, this is only 31 ozs. What is required, then, is the equivalent of 6 inches of slop flint at 31 ozs. to pint in slop flint at 32 ozs. to pint.

It can be shown that this is in the ratio of the figures representing the respective pints weight in ozs. less 20, viz., 11, 12. Hence we multiply the given depth of inches by 11 and divide by 12, thus $\left\{(6 \times 11) \div 12\right\} = 5\frac{1}{2}$.

Similarly with the stone at $30\frac{1}{2}$ ozs. to pint, $(30\frac{1}{2} - 20) = 10\frac{1}{2}$. Then $\left\{(4 \times 10\frac{1}{2}) \div 12\right\} = 3\frac{1}{2}$.

Then we have arrived at the following:—

15 inches	ball-clay slip	at 24 ozs.	to pint.
9 ,,	china-clay ,,	,, 26	,,
$5\frac{1}{2}$,,	slop flint	,, 32	,,
$3\frac{1}{2}$,,	,, stone	,, 32	,,

This, by the simple rule previously given, may be converted to dry weights thus:—

$15 \div 3 = 5$	lbs. of dry	ball-clay.
$9 \div 2 = 4\frac{1}{2}$	,,	china-clay.
$5\frac{1}{2} \div 1 = 5\frac{1}{2}$	,,	flint.
$3\frac{1}{2} \div 1 = 3\frac{1}{2}$	,,	stone.

Then if commercial ball-clay contains, say, 18 per cent. hygroscopic moisture, china-clay 10 per cent., flint 3 per cent., stone 4 per cent., the calculation proceeds thus:—

$(x - \frac{18}{100}x = 5)$ $\therefore x = 6\frac{1}{10}$ lbs. ball-clay
$(x - \frac{10}{100}x = 4\frac{1}{2})$ $\therefore x = 5$,, china-clay
$(x - \frac{3}{100}x = 5\frac{1}{2})$ $\therefore x = 5\frac{2}{3}$,, flint
$(x - \frac{4}{100}x = 3\frac{1}{2})$ $\therefore x = 3\frac{2}{3}$,, stone

} in their average commercial condition of dryness.

TABLE OF THEORETICAL DRY-SUBSTANCE CONTENTS OF SLOP PINTS OF WET-GROUND POTTERS' MATERIALS, FOR KNOWN SPECIFIC GRAVITIES.

Slop-pint Weight.	Sp. Gr. 2·3	Sp. Gr. 2·4	Sp. Gr. 2·5	Sp. Gr. 2·55	Sp. Gr. 2·6	Sp. Gr. 2·7
	Ounces weight of dry material per pint.					
21 oz.	$1\frac{10}{13}$	$1\frac{5}{7}$	$1\frac{2}{3}$	$1\frac{20}{31}$	$1\frac{5}{8}$	$1\frac{10}{17}$
22 oz.	$3\frac{7}{13}$	$3\frac{3}{7}$	$3\frac{1}{3}$	$3\frac{9}{31}$	$3\frac{1}{4}$	$3\frac{3}{17}$
23 oz.	$5\frac{4}{13}$	$5\frac{1}{7}$	5	$4\frac{29}{31}$	$4\frac{7}{8}$	$4\frac{13}{17}$
24 oz.	$7\frac{1}{13}$	$6\frac{6}{7}$	$6\frac{2}{3}$	$6\frac{18}{31}$	$6\frac{1}{2}$	$6\frac{6}{17}$
25 oz.	$8\frac{11}{13}$	$8\frac{4}{7}$	$8\frac{1}{3}$	$8\frac{7}{31}$	$8\frac{1}{8}$	$7\frac{16}{17}$
26 oz.	$10\frac{8}{13}$	$10\frac{2}{7}$	10	$9\frac{27}{31}$	$9\frac{3}{4}$	$9\frac{9}{17}$
27 oz.	$12\frac{5}{13}$	12	$11\frac{2}{3}$	$11\frac{16}{31}$	$11\frac{3}{8}$	$11\frac{2}{17}$
28 oz.	$14\frac{2}{3}$	$13\frac{5}{7}$	$13\frac{1}{3}$	$13\frac{5}{31}$	13	$12\frac{12}{17}$
29 oz.	$15\frac{12}{13}$	$15\frac{3}{7}$	15	$14\frac{25}{31}$	$14\frac{5}{8}$	$14\frac{5}{17}$
30 oz.	$17\frac{9}{13}$	$17\frac{1}{7}$	$16\frac{2}{3}$	$16\frac{14}{31}$	$16\frac{1}{4}$	$15\frac{15}{17}$
31 oz.	$19\frac{6}{13}$	$18\frac{6}{7}$	$18\frac{1}{3}$	$18\frac{3}{31}$	$17\frac{7}{8}$	$17\frac{8}{17}$
32 oz.	$21\frac{3}{13}$	$20\frac{4}{7}$	20	$19\frac{23}{31}$	$19\frac{1}{2}$	$19\frac{1}{17}$
33 oz.	23	$22\frac{2}{7}$	$21\frac{2}{3}$	$21\frac{12}{31}$	$21\frac{1}{8}$	$20\frac{11}{17}$
34 oz.	$24\frac{10}{13}$	24	$23\frac{1}{3}$	$23\frac{1}{31}$	$22\frac{3}{4}$	$22\frac{4}{17}$

TABLES OF EQUIVALENT MEASURES OF CLAY-SLIPS.

For use when mixing ceramic bodies of slips differing in pint weight from the pint weights specified in the recipe.

Ball-clay Slip.								China-clay Slip.								Slop Flint and Stone.							
Pint 22 oz.	Pint 22½ oz.	Pint 23 oz.	Pint 23½ oz.	Pint **24** oz.	Pint 24½ oz.	Pint 25 oz.	Pint 25½ oz.	Pint 24 oz.	Pint 24½ oz.	Pint 25 oz.	Pint 25½ oz.	Pint **26** oz.	Pint 26½ oz.	Pint 27 oz.	Pint 27½ oz.	Pint 29½ oz.	Pint 30 oz.	Pint 30½ oz.	Pint 31 oz.	Pint 31½ oz.	Pint **32** oz.	Pint 32½ oz.	Pint 33 oz.
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
42	33 3/5	28	24	21	18 2/3	16 4/5	15 3/11	27	24	21 3/5	19 7/11	18	16 8/13	15 3/7	14 2/5	10 2/19	9 3/5	9 1/7	8 8/11	8 8/23	8	7 17/25	7 5/13
41	32 4/5	27 1/3	23 3/7	20½	18 2/9	16 2/5	14 10/11	26¼	23 1/3	21	19 1/11	17½	16 2/13	15	14	9 9/19	9	8 4/7	8 2/11	7 19/23	7½	7 1/5	6 12/13
40	32	26 2/3	22 6/7	20	17 7/9	16	14 6/11	25½	22 2/3	20 2/5	18 6/11	17	15 9/13	14 4/7	13 3/5	8 16/19	8 2/5	8	7 7/11	7 7/23	7	6 18/25	6 6/13
39	31 1/5	26	22 2/7	19½	17 1/3	15 3/5	14 2/11	24¾	22	19 4/5	18	16½	15 3/13	14 1/7	13 1/5	8 4/19	7 4/5	7 3/7	7 1/11	6 18/23	6½	6 6/25	6
38	30 2/5	25 1/3	21 5/7	19	16 8/9	15 1/5	13 9/11	24	21 1/3	19 1/5	17 5/11	16	14 10/13	13 5/7	12 4/5	7 11/19	7 1/5	6 6/7	6 6/11	6 6/23	6	5 19/25	5 7/13
37	29 3/5	24 2/3	21 1/7	18½	16 4/9	14 4/5	13 5/11	23¼	20 2/3	18 3/5	16 10/11	15½	14 4/13	13 2/7	12 2/5	7 5/19	6 9/10	6 4/7	6 3/11	6	5¾	5 13/25	5 4/13
36	28 4/5	24	20 4/7	18	16	14 2/5	13 1/11	22½	20	18	16 4/11	15	13 11/13	12 6/7	12	6 18/19	6 3/5	6 2/7	6	5 17/23	5½	5 7/25	5 1/13
35	28	23 1/3	20	17½	15 5/9	14	12 8/11	21¾	19 1/3	17 2/5	15 9/11	14½	13 5/13	12 3/7	11 3/5	6 12/19	6 3/10	6	5 8/11	5 11/23	5¼	5 1/25	4 11/13
34	27 1/5	22 2/3	19 3/7	17	15 1/9	13 3/5	12 4/11	21	18 2/3	16 4/5	15 3/11	14	12 12/13	12	11 1/5	6 6/19	6	5 5/7	5 5/11	5 5/23	5	4 4/5	4 8/13
33	26 2/5	22	18 6/7	16½	14 2/3	13 1/5	12	20¼	18	16 1/5	14 8/11	13½	12 6/13	11 4/7	10 4/5	6	5 7/10	5 3/7	5 2/11	4 22/23	4¾	4 14/25	4 5/13
32	25 3/5	21 1/3	18 2/7	16	14 2/9	12 4/5	11 7/11	19½	17 1/3	15 3/5	14 2/11	13	12	11 1/7	10 2/5	5 13/19	5 2/5	5 1/7	4 10/11	4 16/23	4½	4 8/25	4 2/13
31	24 4/5	20 2/3	17 5/7	15½	13 7/9	12 2/5	11 3/11	18¾	16 2/3	15	13 7/11	12½	11 7/13	10 5/7	10	5 7/19	5 1/10	4 6/7	4 7/11	4 10/23	4¼	4 2/25	3 12/13
30	24	20	17 1/7	15	13 1/3	12	10 10/11	18	16	14 2/5	13 1/11	12	11 1/13	10 2/7	9 3/5	5 1/19	4 4/5	4 4/7	4 4/11	4 4/23	4	3 21/25	3 9/13
29	23 1/5	19 1/3	16 4/7	14½	12 8/9	11 3/5	10 6/11	17¼	15 1/3	13 4/5	12 6/11	11½	10 8/13	9 6/7	9 1/5	4 14/19	4 5/10	4 2/7	4 1/11	3 21/23	3¾	3 3/5	3 6/13
28	22 2/5	18 2/3	16	14	12 4/9	11 1/5	10 2/11	16½	14 2/3	13 1/5	12	11	10 2/13	9 3/7	8 4/5	4 8/19	4 1/5	4	3 9/11	3 15/23	3½	3 9/25	3 3/13
27	21 3/5	18	15 3/7	13½	12	10 4/5	9 9/11	15¾	14	12 3/5	11 5/11	10½	9 9/13	9	8 2/5	4 2/19	3 9/10	3 5/7	3 6/11	3 9/23	3¼	3 3/25	3
26	20 4/5	17 1/3	14 6/7	13	11 5/9	10 2/5	9 5/11	15	13 1/3	12	10 10/11	10	9 3/13	8 4/7	8	3 15/19	3 3/5	3 3/7	3 3/11	3 3/23	3	2 22/25	2 10/13
25	20	16 2/3	14 2/7	12½	11 1/9	10	9 1/11	14¼	12 2/3	11 2/5	10 4/11	9½	8 10/13	8 1/7	7 3/5	3 9/19	3 3/10	3 1/7	3	2 20/23	2¾	2 16/25	2 7/13
24	19 1/5	16	13 5/7	12	10 2/3	9 3/5	8 8/11	13½	12	10 4/5	9 9/11	9	8 4/13	7 5/7	7 1/5	3 3/19	3	2 6/7	2 8/11	2 14/23	2½	2 2/5	2 4/13
23	18 2/5	15 1/3	13 1/7	11½	10 2/9	9 1/5	8 4/11	12¾	11 1/3	10 1/5	9 3/11	8½	7 11/13	7 2/7	6 4/5	2 16/19	2 7/10	2 4/7	2 5/11	2 8/23	2¼	2 4/25	2 1/13
22	17 3/5	14 2/3	14 4/7	11	9 7/9	8 4/5	8	12	10 2/3	9 3/5	8 8/11	8	7 5/13	6 6/7	6 2/5	2 10/19	2 2/5	2 2/7	2 2/11	2 2/23	2	1 23/25	1 11/13
21	16 4/5	14	12	10½	9 1/3	8 2/5	7 7/11	11¼	10	9	8 2/11	7½	6 12/13	6 3/7	6	2 4/19	2 1/10	2	1 10/11	1 19/23	1¾	1 17/25	1 8/13
20	16	13 1/3	11 3/7	10	8 8/9	8	7 3/11	10½	9 1/3	8 2/5	7 7/11	7	6 6/13	6	5 3/5	1 17/19	1 4/5	1 5/7	1 7/11	1 13/23	1½	1 11/25	1 5/13

THE STAFFORDSHIRE POTTERIES SLOP FLINT AND STONE TRADE CALCULATOR.

(ABRIDGED.)

General Rule for ascertaining the number of 32 lbs. pecks equivalent to given machine and pint weights. } *Divide the net machine weight in lbs. by the pint weight in ozs.; this gives the number of pecks by measure. Multiply this number by the pint weight in ozs. less* 20, *and divide by* 12.

Machine Weight 112 lbs. to 1 cwt. Cwts.	qrs.	Pint 30½ ozs.	Pint 30¾ ozs.	Pint 31 ozs.	Pint 31¼ ozs.	Pint 31½ ozs.	Pint 31¾ ozs.	Pint 32 ozs.	Pint 32¼ ozs.	Pint 32½ ozs.	Pint 32¾ ozs.	Pint 33 ozs.	Pint 33¼ ozs.	Pint 33½ ozs.
		32 lbs. Pecks.	32 lbs. Pecks.	32 lbs. Pecks.	32 lbs. Pecks.	32 lbs. Pecks.	32 lbs. Pecks.	32 lbs. Pecks.	32 lbs. Pecks.	32 lbs. Pecks.	32 lbs. Pecks.	32 lbs. Pecks.	32 lbs. Pecks.	32 lbs. Pecks.
18	0	57¾	58¾	59½	60½	61¼	62¼	63	63¾	64½	65½	66¼	67	67¾
18	1	58¾	59½	60½	61¼	62¼	63	63¾	64¾	65½	66¼	67	67¾	68½
18	2	59½	60¼	61¼	62¼	63	64	64¾	65½	66½	67¼	68	68¾	69½
18	3	60¼	61¼	62	63	63¾	64¾	65½	66½	67¼	68	69	69¾	70½
19	0	61	62	63	63¾	64¾	65½	66½	67½	68¼	69	69¾	70¾	71½
19	1	61¾	62¾	63¾	64¾	65½	66½	67¼	68¼	69	70	70¾	71½	72½
19	2	62¾	63¾	64½	65½	66½	67¼	68¼	69	70	70¾	71¾	72½	73¼
19	3	63½	64½	65¼	66¼	67¼	68¼	69	70	70¾	71¾	72¾	73½	74¼
20	0	64¼	65¼	66¼	67¼	68	69	70	71	71¾	72½	73½	74¼	75¼
20	1	65	66	67	68	69	70	70¾	71¾	72¾	73½	74½	75¼	76¼
20	2	65¾	66¾	68	68¾	69¾	70¾	71¾	72¾	73½	74½	75½	76¼	77
20	3	66¾	67¾	68¾	69¾	70¾	71¾	72½	73½	74½	75½	76¼	77¼	78
21	0	67½	68½	69½	70½	71½	72½	73½	74½	75¼	76¼	77¼	78	79
21	1	68¼	69¼	70¼	71½	72½	73½	74¼	75¼	76¼	77¼	78	79	80
21	2	69	70	71¼	72¼	73¼	74¼	75¼	76¼	77¼	78	79	80	80¾
21	3	70	71	72	73	74	75	76	77	78	79	80	81	81¾
22	0	70¾	71¾	72¾	74	75	76	77	78	79	79¾	80¾	81¾	82¾
22	1	71½	72½	73¾	74¾	75¾	76¾	77¾	79	79¾	80¾	81¾	82¾	83¾
22	2	72¼	73½	74½	75½	76½	77¾	78¾	79¾	80¾	81¾	82¾	83¾	84¾
22	3	73	74¼	75¼	76½	77½	78½	79½	80¾	81½	82¾	83¾	84½	85½
23	0	74	75	76¼	77¼	78¼	79½	80½	81½	82½	83½	84½	85½	86½
23	1	74¾	75¾	77	78	79¼	80¼	81¼	82½	83½	84½	85½	86½	87½
23	2	75½	76¾	77¾	79	80	81¼	82¼	83¼	84¼	85½	86½	87½	88¼
23	3	76¼	77½	78½	79¾	81	82	83	84¼	85¼	86¼	87¼	88¼	89¼
24	0	77	78¼	79½	80½	81¾	82¾	84	85	86¼	87¼	88¼	89¼	90¼

The fractions used in the above table of standard pecks equivalent to given machine and pint weights are the closest approximate quarter units. For the absolutely exact fractions, which, however, are commercially impracticable, see *Explanation of the Staffordshire Potteries Slop Flint and Stone Trade Calculator*, published by W. J. Furnival, Stone.

Preparing the Dusts.—The methods described in Chapter V. are followed precisely in case of dusts for glazing tiles, except that in the case of embossed tiles the dust should be damped on plaster beds in preference to using the disintegrating and damping machine, because the dusts have to be used in a more humid state, to secure perfect impressions.

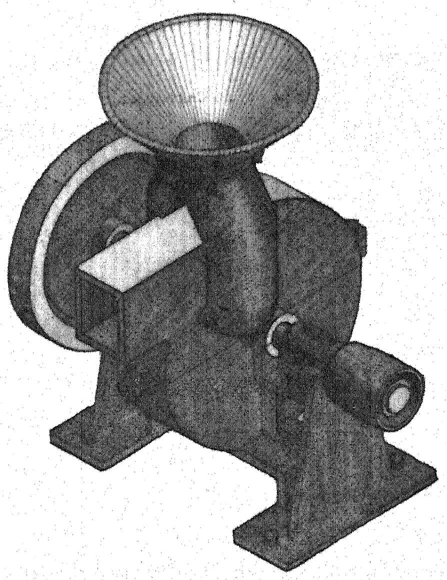


FIG. 248.—Crossley's dust-mill or disintegrator.

Plain Tile-Pressing.—The presses and processes are similar to those described in the chapter on floor-tiles; but the thickness of glazed tiles is usually only $\frac{3}{8}$ of an inch when burned, and this requires only a depth of dust in the mould of about 1 inch. If $\frac{1}{2}$-inch thick tiles are required, the mould die must allow $1\frac{1}{4}$ inch of clay-dust.

The relative size of die or mould to tile, however, is frequently less than with floor-tiles, because the shrinkage of glazing tile-bodies is usually less.

Thus for a 6-inch by 6-inch tile the die or mould may only be from $6\frac{1}{4}$ inches by $6\frac{1}{4}$ inches to $6\frac{7}{16}$ inches by $6\frac{7}{16}$ inches, other sizes in proportion; and this difference in shrinkage also slightly affects the thickness. If sizes become wrong, then the means of correction must be sought in one of the following expedients:—

(*a*) Alter the body formula.
(*b*) Vary the ingredients.
(*c*) Burn the tiles in another part of the kiln or oven.
(*d*) Burn the whole of the oven differently.
(*e*) Alter the sizes of dies and moulds.

When the joints of a tile-box open out at all, it is preferable to have them immediately mechanically readjusted, as any alterations in firing or in composition may affect the porosity, and so contribute to lack of uniformity in several respects when glazed.

The simple effect of burning tiles in different parts of the kiln or oven is well exemplified in the diagram, fig. 250. The tiles indicated were made of precisely the same body composition, pressed at the same time consecutively, and in the same dies, and burned in the same kiln or oven, but in different parts of the kiln or oven.

For small sizes of tiles, double dies may be used, to facilitate and economize

production; and for large sizes, such as 12-inch by 6-inch and 8-inch by 8-inch, greater care and more operatives to a press are required, and special attention paid to the humidity of the dust-clay used, and to the flatness of

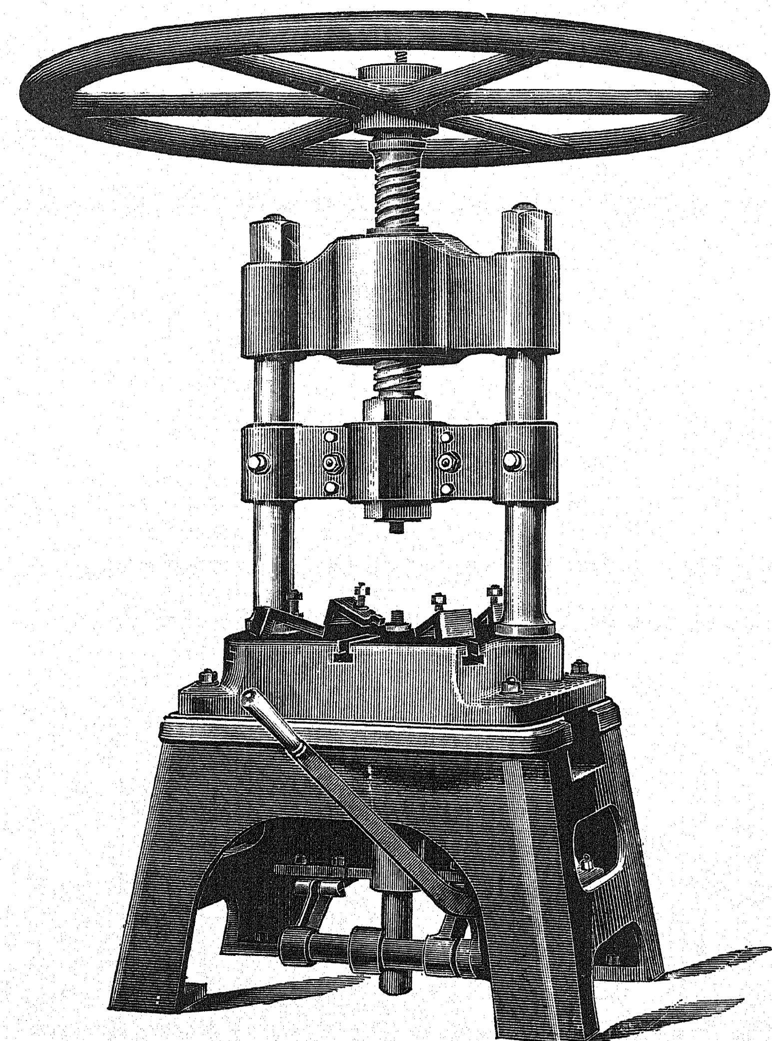
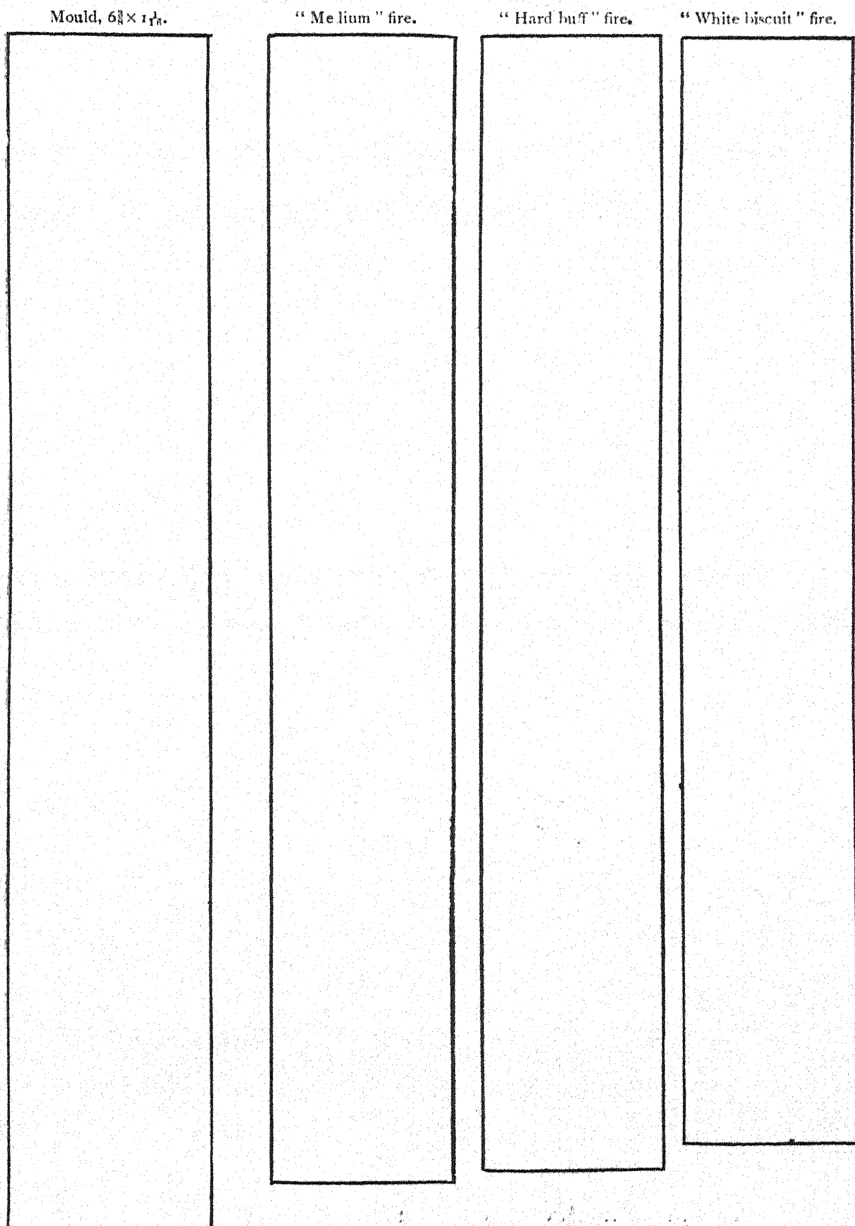


FIG. 249.—Tile-press for large sizes—pillar pattern. (*By W. Boulton, Ltd., Burslem.*)

the bats or burnt-tile setters upon which the clay-tiles are laid when fettled. Drying also in such cases needs to be conducted more slowly, and is best effected in heated closed chambers, to avoid strong air-currents.

Ornamental mouldings, beadings, skirtings, corner tiles, etc., may be made

FIG. 250.—Diagram of shrinkage during drying and burning of the same body at different heats in the same kiln.



from clay-dust in suitable dies and moulds. In the case of angle or cove tiles, they should be smooth on both concave and convex surfaces, so that either side may be glazed as required.

Embossed Tiles.—To produce low-relief embossed tiles, it is first necessary to make a drawing of the desired pattern, to a shrinkage scale appropriate to the body to be used; then prepare a slab of modelling clay, slightly larger than required by the design, the surface of this clay slab to be got as perfectly level and true as practicable (fig. 251).

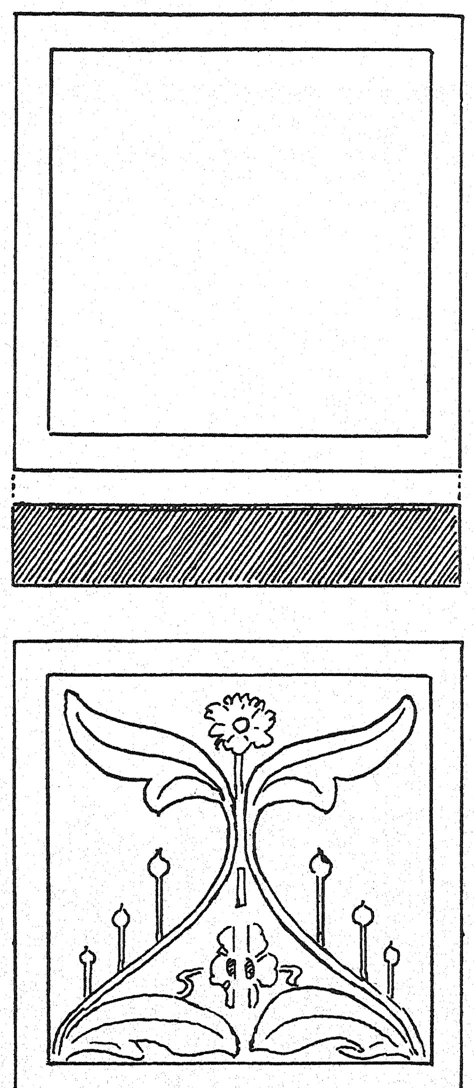


FIG. 251.—Modelling embossed tiles.

The desired embossment must then be modelled on the slab of clay in relievo or intaglio, in accordance with the style and effect desired, bearing in mind that the model must be made so that it will liberate the mould easily, or draw well; therefore no undercutting is admissible. When the model is finished a plaster mould should then be made of it. To do this a "cottle" of clay or wood should be put around the margin $1\frac{1}{2}$ inch to 2 inches high, and the plaster mixed and run in slowly to avoid air-bubbles. When this has set quite firm, turn over the mould, take out the clay, and clean the mould thoroughly with water.

If it needs "touching up" or further modelling of any little detail, now is the proper time.

When the foregoing has been completed, size the plaster mould for a few seconds, and then wash the size off with water and sponge the mould dry. Repeat this sizing process four times, allowing about two minutes' rest or interim between each sizing. When sizing for the last time water must not be used, but the mould should be sponged with

size, care being taken to clean it thoroughly with the sponge or with a camel-hair brush. The size should consist of soft soap and water: to half a pound of soft soap add a quart of boiling water, and mix up together.

For mixing the plaster, get the quantity of cold water you think will be enough for the mould, in a wide-mouthed jug, then put in plaster little by little until it appears slightly above the surface of the water, like a little island; so let it remain at rest a few moments, then mix all up thoroughly to a creamy consistence, taking care to rub down lumps of plaster, and also avoiding the intermixing of air-bubbles. It will then be ready for use, and may be poured upon or run into the model.

The plaster mould, when finished, sized, and dried, may be handed over to the iron or brass founder to enable him to make a sand impression of the necessary exactness, from which the required embossed brass or fine iron plate is cast; and this usually is about $\frac{3}{8}$ of an inch thick. After casting, the edges of the plate must be planed true to fit the dies and mould of the press.

A summary of the method of proceeding for the production of this plate may be expressed briefly thus:—

1. The design and drawing.
2. Clay model in relief as the tile will be.
3. Plaster mould from the clay model.
4. Sand impression in relief as the tile is to be.
5. Cast-metal plate from the sand impression.
6. Tile made in relief from the brass or cast-metal plate.

The embossing plates so made are either placed on the bottom plunger and covered with clay-dust, and the tile then pressed in the ordinary manner; or, on the other hand, the mould of the press may be filled with clay-dust, and the embossed plate laid on the top and so pressed.

The dust-clay of which embossed tiles are pressed is usually damped in plaster beds, to secure greater humidity, and thus enable the tiles to leave the dies more satisfactorily.

As the tiles are made, a thick layer of fine silver-sand should be scattered between each to prevent injury to the embossment when they are placed upon each other in heaps on the bats or setters ready to be carried off for drying.

Drying.—Bath-tiles and glazing tiles generally, as they are removed from the press in the clay state, being usually only $\frac{3}{8}$ of an inch thick, need care in handling and fettling, and must be laid on burnt-tiles or setters as perfectly level as practicable, face to face and back to back, alternately, in bungs of about eight tiles high, a little sand being scattered on the back of the top tile and a top setter-tile bedded on this sand.

The bungs may then be put aside in a cool room for a few days to condition, and then moved into a slightly heated room, then into a closed

heated chamber free from draughts, when, after seven or ten days, according to the size of the tile, they may be dry enough for placing in the saggars.

Placing and Setting in.—The bungs of tiles eight or ten high should be taken from the drying-room and placed in oblong-shaped saggars, two heaps or bungs in a saggar, side by side, small tiles being arranged upon 6-inch by 6-inch bats or setters, so as to form bungs equivalent to those of 6-inch by 6-inch tiles.

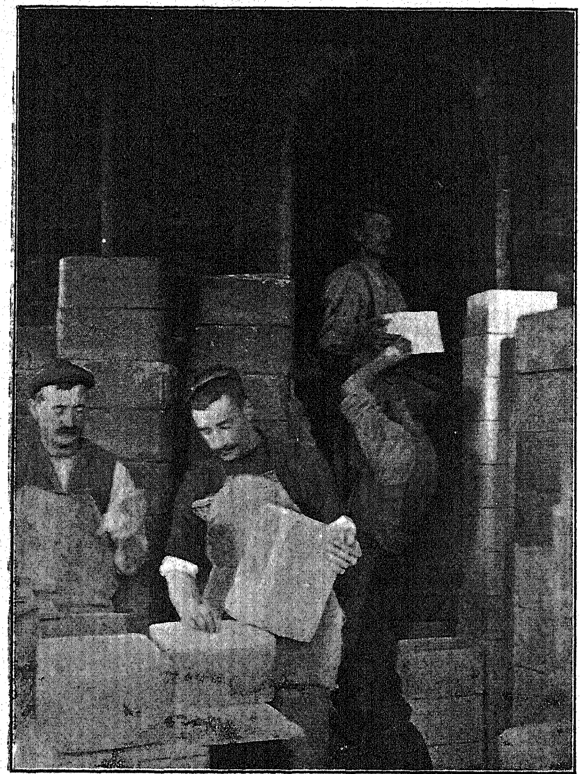


FIG. 252.—Saggars and kiln. (*From Carter & Co.'s "Interesting Notes on Ornamental Tile Manufacture."*)

Different-coloured tiles should be in separate bungs and separate saggars.

When setting these saggars in the kiln or oven, bath-tiles and most glazing tiles should as far as convenient be set in the second and third rings, *i.e.*, when flooring-tiles are to be burned in same oven.

When glazing tiles alone are burned, the setting in the oven will then be regulated in accordance with the different-coloured bodies concerned and their relation to the heat attained.

If plastic-made faience, such as kerbs, plaques, slabs, plinths, pilaster blocks, friezes, mouldings, etc., are fired in the same kiln, these may be placed in rather easily fired parts by preference, if necessary. Large pieces may be papered over and set in built-up, pigeon-holed firebrick boxes built within the oven.

Burning.—Plans of kilns and ovens will be found in other chapters, and need not be repeated here. Respecting the practical work of burning, the notes in Chapter VII. will perhaps be found serviceable. One experienced fireman tersely expresses the method as consisting of "one night's smoking and two nights' firing." The temperatures usually attained differ in a measure at different works, because in the one instance possibly large quantities of

white-glazed bath and dairy tiles or earthenware wall-tiles may be made, while at another works only heavily-glazed majolica tiles may be made.

The range of temperatures given in Mr. Watkin's pamphlet respecting his heat recorders may be tabulated as under:—

	Recorder No.	Temperature.
Earthenware biscuit, ...	17-25	1030° C.-1190° C.
Hard earthenware biscuit, . . .	19-27	1070° C.-1230° C.
Tile biscuit, ...	21-29	1110° C.-1270° C.

But he has shown elsewhere that much depends upon the thickness of the ware and the compactness with which it can be packed into the kiln. And as tile kilns or ovens necessarily contain very great weight and very solid masses, more time and heat are needed comparatively.

Sorting.—Little need be added under this head to the suggestions in Chapter VII., which in a great measure apply in this case, except that special care must be taken in selecting best white tiles, in order to turn out specked, nipped, uneven, or cracked tiles, which should be placed together in their respective classes.

Faience, such as kerbs, friezes, skirting mouldings, and the like, will all need sorting in the biscuit state; and portions of mantelpieces, pilasters, etc., in many instances should be fitted together, and, if necessary, ground or stopped, as required, at this stage; so that, after careful and satisfactory dipping and firing, the pieces will be complete in the sets required, and so ready for dispatch. If, on the other hand, the grinding is delayed until the pieces are glazed, there is always a risk of the glaze chipping off, if grinding is then resorted to.

RECIPES FOR WHITE GLAZING TILE-BODIES.

No. 1.—White Glazing Body.

5 cwts. best ball-clay, dry 6 " " china-clay, " 8½ " ground calcined flint 2½ " " Cornish china-stone	very slightly stained with blue stain if so desired.

No. 2.—White Glazing Body (wet mixing).

15 inches	ball-clay slip	at 24 ozs.	to pint.
12 "	china-clay "	" 26	"
8½ "	slop flint	" 32	"
2½ "	" stone	" 32	"

No. 3.—White Glazing Body.

4 cwts. blue ball-clay.
6 „ best china-clay (kaolin).
8 „ ground calcined flint.
$2\frac{1}{2}$ „ „ Cornish china-stone.
7 lbs. finely ground smalt.

No. 4.—White Glazing Body (wet mixing).

14 inches	ball-clay slip	at	24 ozs.	to pint.
$10\frac{1}{2}$ „	china-clay „	„	26	„
$10\frac{1}{4}$ „	slop flint	„	32	„
$4\frac{3}{4}$ „	„ stone	„	32	„

No. 5.—White Glazing Body.

50 lbs. blue ball-clay.
50 „ china-clay (kaolin).
100 „ ground flint.
50 „ „ china-stone.

No. 6.—White Glazing Body (bath-tile body).

430 lbs. blue ball-clay.
404 „ best china-clay (kaolin).
560 „ ground calcined flint.
252 „ „ Cornish china-stone.

No. 7.—White Glazing Body (for inlay slips).

22 lbs. blue ball-clay.
$30\frac{1}{2}$ „ best china-clay (kaolin).
25 „ ground calcined flint.
12 „ „ Cornish china-stone.

No. 8.—White Glazing Body (common and barbotine).

500 lbs. blue ball-clay.
340 „ strong china-clay.
550 „ ground calcined flint.

No. 9.—White Glazing Body (common).

308 lbs. blue ball-clay.
532 „ ground white earthenware biscuit pitchers.
168 „ „ calcined flint.
84 „ china-clay.

RECIPES FOR IVORY-TINTED GLAZING TILE-BODIES.

No. 1.—Ivory Glazing Body.

5 cwts. ivory ball-clay.
5 „ common china-clay.
8 „ ground calcined flint.
3 „ „ Cornish china-stone.

No. 2.—Ivory Glazing Body.

5 cwts. ivory ball-clay.
4 „ common china-clay.
5 „ ground calcined flint.
2 „ „ Cornish china-stone.

No. 3.—Ivory Glazing Body (dark).

$7\frac{3}{4}$ cwts. dark ivory ball-clay.
$3\frac{3}{8}$ „ common china-clay.
$7\frac{1}{2}$ „ ground calcined flint.
3 „ „ Cornish china-stone.

RECIPES FOR CREAM-TINTED GLAZING TILE-BODIES.

No. 1.—Cream Glazing Body.

5 cwts. siliceous buff ball-clay (Dorset).
3 „ black ball-clay (Dorset).
2 „ common china-clay.
$1\frac{1}{2}$ „ ground calcined flint.
$\frac{3}{4}$ „ „ Cornish china-stone.

No. 2.—Cream Glazing Body.

3 cwts. siliceous buff ball-clay (Dorset).
2 „ ivory ball-clay.
2 „ common china-clay.
$3\frac{1}{4}$ „ ground calcined flint.
$1\frac{1}{2}$ „ „ Cornish china-stone.

No. 3.—Cream Glazing Body.

5 cwts. black ball-clay (Dorset).
4 „ ground calcined flint.

No. 4.—Cream Glazing Body.

5 cwts. common ivory ball-clay.
3 „ ground white earthenware biscuit pitchers.
1½ „ „ calcined flint.

No. 5.—Cream Glazing Body.

12 cwts. ivory ball-clay.
12 „ ground silica rock.
4 „ „ china-stone.

RECIPES FOR BUFF GLAZING TILE-BODIES.

No. 1.—Buff Glazing Body.

200 lbs. ivory ball-clay (common, stained).
160 „ ground calcined flint.

No. 2.—Buff Glazing Body.

16 cwts. ivory ball-clay (common, stained).
10 „ ground calcined flint.
2 „ „ Cornish china-stone.

No. 3.—Buff Glazing Body.

4 cwts. siliceous buff ball-clay.
4 „ black ball-clay (Dorset).
1 „ ground calcined flint.
½ „ „ china-stone.

No. 4.—Buff Glazing Body.

4 cwts. dark ivory ball-clay.
2 „ ground earthenware biscuit pitchers.
1 „ „ calcined flint.

No. 5.—Buff Glazing Body.

7 cwts. siliceous buff ball-clay.
2 „ stained ivory „
1 „ ground calcined flint.
1 „ best selected cane marl.

No. 6.—Orange-Buff Glazing Body.

8 cwts. siliceous yellow clay (Dorset).
2 „ superior cane marl.
½ „ ground Cornish china-stone.

RECIPES FOR CANE-TINTED GLAZING TILE-BODIES.

No. 1.—Cane Glazing Body (light).

3 cwts. black ball-clay (Dorset).
2 „ sieved superior cane marl, weathered.
3¼ „ ground calcined flint.
1⅛ „ „ Cornish china-stone.

No. 2.—Cane Glazing Body.

5 cwts. sieved superior cane marl, weathered.
1½ „ black ball-clay (Dorset).
1¼ „ common china-clay.
2 „ ground calcined flint.
½ „ „ Cornish china-stone.

No. 3.—Cane Glazing Body.

40 cwts. sieved superior cane marl, weathered.
20 „ ground white earthenware biscuit pitchers.
5 „ ivory ball-clay.

No. 4.—Cane Glazing Body.

Superior cane or buff marl from the coal-measures, carefully selected and weathered.

RECIPES FOR SALMON-PINK GLAZING TILE-BODIES.

No. 1.—Salmon-Pink Glazing Body.

9 lbs. blue ball-clay.
12 „ china-clay (kaolin).
12 „ ground calcined flint.
5 „ „ Cornish china-stone.
2 „ „ calcined Japanese red.

No. 2.—Salmon-Pink Glazing Body.

11 lbs. blue ball-clay.
19 „ ground white earthenware biscuit pitchers.
6 „ „ calcined flint.
3 „ china-clay (kaolin).
2 „ ground calcined Japanese red.

No. 3.—Salmon-Pink Glazing Body (for inlays).

10 lbs. No. 7 white glazing tile-body slip at 28 ozs. to pint.
$3\frac{3}{4}$ ozs. ground calcined Japanese red.

RECIPES FOR BLUE GLAZING TILE-BODIES

No. 1.—Blue Glazing Body.

23 lbs. white glazing tile-body No. 7.
1 „ finely ground blue stain.

Blue Stain.

8 lbs. oxide of zinc		
4 „ „ „ cobalt		calcined and ground.
2 „ felspar		
2 „ ground flint		

No. 2.—Blue Glazing Body (for inlay slips).

10 lbs. No. 7 white glazing tile-body slip at 28 ozs. to pint.
$3\frac{1}{4}$ ozs. finely ground blue stain (see above).

No. 3.—Blue Glazing Body (celeste).

18 lbs. No. 9 white glazing body.
1 oz. ground blue stain (as above).
$\frac{1}{2}$ „ „ oxide of copper.

RECIPE FOR DOVE GLAZING TILE-BODY.

No. 1.—Dove Glazing Body (for inlays).

20 lbs. No. 7 white glazing tile-body slip at 28 ozs. to pint.
$\frac{1}{4}$ oz. finely ground black oxide of copper.
$\frac{1}{2}$ „ „ „ blue stain (see as above).

RECIPES FOR CELADON GLAZING TILE-BODIES.

No. 1.—Celadon Glazing Body.

18 lbs. white glazing tile-body.
$\frac{1}{4}$ „ finely ground black oxide of copper.

No. 2.—Celadon Glazing Body (for inlays).

12 lbs. No. 7 white glazing tile-body slip at 28 ozs. to pint.
$1\frac{1}{4}$ ozs. finely ground black oxide of copper.

RECIPE FOR GREEN GLAZING TILE-BODY.

No. 1.—Green Glazing Body (for inlays).

10 lbs. No. 7 white glazing tile-body slip at 28 ozs. to pint.
$5\frac{1}{2}$ ozs. finely ground green oxide of chrome.

RECIPES FOR SILVER-GREY GLAZING TILE-BODIES.

No. 1.—Silver-Grey Glazing Body.

18 lbs. No. 9 white glazing tile-body.
$\frac{1}{4}$ „ finely ground "bulldog" iron-furnace waste.

No. 2.—Silver-Grey Glazing Body (for inlays).

48 lbs. No. 7 white glazing tile-body slip at 28 ozs. to pint.
$2\frac{1}{2}$ ozs. finely ground "bulldog" iron-furnace waste.

RECIPE FOR BLACK GLAZING TILE-BODY.

No. 1.—Black Glazing Body (for easy fire).

28 lbs. siliceous red marl, weathered.
1 „ ground "bulldog" iron-furnace waste.
1 „ „ manganese ore.

RECIPES FOR BROWN GLAZING TILE-BODIES.

No. 1.—Brown Glazing Body.

36 lbs. siliceous red marl, weathered.
$\frac{1}{4}$ „ ground "bulldog" iron-furnace waste.
$\frac{1}{4}$ „ „ ground manganese ore.

No. 2.—Brown Glazing Body (dark).

Chocolate floor-tile body, burned rather easily in biscuit oven.

RECIPES FOR RED GLAZING TILE-BODIES.

No. 1.—Red Glazing Body.

112 lbs. siliceous red marl, weathered.
2 „ ground Cornish china-stone.

No. 2.—Red Glazing Body.

8 cwts. Leckhampton red clay.
4 „ siliceous yellow clay (Dorset).
½ „ ground calcined flint.
½ „ china-clay (kaolin).

No. 3.—Red Glazing Body.

112 lbs. mixed red marls, weathered.
112 „ cane marl, weathered.

No. 4.—Red Glazing Body.

Great Harwood (Lancashire) shale alone, suitably prepared.

CHAPTER X.

UNDERGLAZE DECORATIVE PROCESSES.

CONTENTS.—Slip-painting—Barbotine—Recipes for coloured slips—*Pâte-sur-pâte*—Parian—*Sgraffito*—Biscuit-painting—Printing—Roller printing machines—Underglaze colours—Aerograph.

FIG. 253.—Printed tile, leadless glazed.

IN addition to relief or modelled treatment of the tile surface, such as embossing, incising, roughening, raised line, *cloisonné*, inlaying, and the like, chromo-decorative treatment under the glaze is also extensively practised.

Perhaps the most customary modes of colour-treatment are slip-painting, barbotine, *pâte-sur-pâte*, *sgraffito*, biscuit-painting, biscuit-printing, and aerography, their use at different periods extending or declining with the ebbs and flows of fashion and enterprise.

Slip-Painting; Barbotine.—Ornamentation by means of semi-fluid clay-slips, if not the most ancient of all known processes of pottery decoration, must at least rank next after that of simple incision. As a ceramic process, slip-decoration is equally primæval, ancient, mediæval, and modern; it may be coarse or æsthetic, simple or subtle, monochrome or polychrome, and so forms a gauge of the artistic perceptions of those who make use of it.

Professor Petrie tells of people of Upper Egypt, of predynastic age, whose pottery was ornamented with white slip almost identical in colour and style with that of the Kabyles who inhabit mountainous regions in Algeria to-day.

Slip-painting appears on Archaic-Greek wares, on Hellenic-Greek wares, on Roman and early Italian wares; crude to a degree on the ceramic absurdities of ancient Peru, simple if not vulgar on early English tygs and dishes, advancing in merit on Wheildon ware, and at last leaping into truly artistic expression upon European products of the closing decades of the

nineteenth century; Danes, French, British, and Americans particularly distinguishing themselves in its development and application.

The writer is informed that slip-painting is done on decorative tiles in great quantities, and that it may be effected either on damp, freshly made, undried dust-clay tiles, in the clay state, or on the same slightly baked.

When applied on dust-tiles in the clay state, the tiles should be made of specially damped clay-dust, and preferably of relatively more aluminous body, to retard drying.

In the case of large slabs of faience, and large tiles which are subject to warping or buckling when treated with wet applications, the process is often modified by first slightly baking the piece, and afterwards soaking in water, prior to decorating with slips.

Another term, viz., *barbotine*, has come into general use in connection with slip-decoration; in plain English this means little more than slip-painting, for Brongniart himself translates the word "slip." It probably originates from the French verb *barbotter*, to dabble as ducks dabble in a puddle; but, as now employed technically in the British tile trade, the term "barbotine" signifies something more than the mere application of clay-slips. It rather denotes fine-art painting with various complex-coloured slips, not pure clays by any means, but compounded more or less of chemically prepared ceramic colours, and for finishing touches the pure colours themselves are used.

FIG. 254.—Lilies. *By Mussill.*

Fig. 254 is an example of high-class work of this style, being a group of lilies from or in Trentham Gardens, painted in this style by that noted and venerable pottery artist Mussill.

After completion of the decoration, and a further rather easy biscuit-burning, plaques or tiles, or other pieces embellished by the barbotine process, are glazed over with an easily fusible glaze, and are then usually burned in a glaze kiln at a comparatively low temperature, so that the soft glaze may not attack and injure the colours underneath.

Hence, at times, when the work has been badly done in a technical sense, or the burning too leniently or unsuitably effected, the product may prove to be not sufficiently durable.

When slip-decoration is applied to unbaked pieces of plastic-made clay-ware, these should, during decoration, be constantly maintained in as even a condition of dampness as practicable, not too soft, nor too dry, and should be placed in a damped plaster safe or cellar when not under treatment. Immediately before commencing the application of the coloured slips, from time to time the surfaces of the piece should be slightly moistened with pure water. Care must be exercised also with regard to the consistence of the slips; a condition of batter often being more suitable than thinner slips. To preserve their condition as evenly as possible, the slips should be kept in wide-mouthed bottles, and corked up when not wanted.

Skilful artists say that the best medium is pure soft water. If gelatine or gum is introduced, the slips may curl off; and if glycerine or syrup is added to the water, the painting is liable to work up at each successive application. Sir C. Purdon Clarke states that gums and starches are much used by Hindoo ceramic artists; but, so far as the writer's personal experience goes, water alone seems to be best. To increase the tenacity of engobes, soda solution is sometimes added, and may in some cases be of service in the slips.

Langenbeck, however, declares that the question of the serviceability of a slip for decorative purposes is one that can only be learned by experiment. He writes:—"Slips for ornamenting wares . . . . are made by softening white plastic clays or mixtures resembling the whiteware bodies . . . . in water, and passing the creamy mixture through a fine sieve. For engobing ware, as in the case of the Pennsylvania Dutch potteries, this slip is left liquid enough to allow the pieces to be immersed in it, and remain, after their withdrawal, covered with a smooth, entirely opaque deposit. For painting, the slip is thickened to the consistence of common tube-paints and colored with metallic oxides. In either case the question for the chemist is the selection of a white clay or mixture that does not crack or shell off from the particular clay upon which it is to be applied during the processes of drying and firing. This selection can only be made by empiric trials, as differences in shrinkage, both during the first step of drying and the second of burning, between the body and the slip applied to it, differences too subtle for direct measurement, would be fatal to the result." (*Chem. of Pottery*, p. 65.)

But on account of the many demands on the artist's time and attention, and the many risks of losses in process of manufacture, painting of clay-slips on "green," *i.e.*, unbaked clayware, so far as the decoration of dust-made tiles is concerned, has been partially abandoned in favour of a similar process applied to easily baked tiles. By this method the pieces are baked lightly before decorating, and the slips compounded to suit biscuit-ware.

This process has the very great advantage of rendering eligible for treatment all dust-made tiles and slabs, as well as plastic-made pieces, and results in the

production of truer work, besides escaping a lot of the troubles and risks associated with the unbaked-clay treatment.

In compounding the slips for this adaptation of slip-painting, more calcined material in a finely ground state is added, to reduce shrinkage, and less plastic clay introduced. But still considerable judgment must be exercised in preparing the compositions, for excess of silica may cause the slips to shell off, and excess of pure kaolin may induce weakness in the work and want of cohesion to the piece. Sometimes a small proportion of vitrescent flux is added, partly to secure better attachment of the decoration to the ware, and partly to increase the liveliness of the colours; but this is very liable to cause curling off during the burning.

The nature of the body of the ware itself has a great influence for better or for worse in the results; a too plastic body, or one upon which thin, surface, skin-like exudations rise—particularly soluble ferruginous ones—are very likely to prevent cohesion.

The writer's experiments point very conclusively to the following as a suitable composition for the body of tiles which are to be used for slip-painting on easy biscuit-ware :—

500 lbs. ball-clay.
340 „ china-clay.
550 „ flint.

Finally, behind the slips and colours and brushes and water there must be a practically trained manipulator, possessing artistic perceptions and matured skill. Directions, however minute and accurate, cannot of themselves impart artistic qualifications; nevertheless, an outline description of the technicalities and sequence of a single example of barbotine decoration may be suggestive and serviceable to the uninitiated.

Taking as an example a kingfisher, an experienced artist described his method in substance as follows :—Prepare a slip consisting of six parts by weight of No. 1 white, weighed dry, and one part by weight of black oxide of copper, ground together in water on a slab; then moisten the part of the panel, or other piece of ware, where the kingfisher is to be painted, with soft water, then with a thin wash of the slip-colour just mentioned cover all over where the kingfisher is to go, so as to obscure the ground or body of the ware. Then take twelve parts more of white and mix it with the above-named composition, and paint the bird in (this, when subsequently burned and glazed, will be a turquoise tint). To get the blue on head and wings, paint those portions with slip of cobalt blue (a dull pinkish-tinted mixture prepared by potters' colourmakers by fluxing the oxide of cobalt with china-stone, etc., and calcining the compound). On the breast use slips of underglaze orange colour and underglaze brown, singly as required, to give the requisite effect.

For the darker touches use underglaze black and underglaze dark green ceramic colour slips.

After the decoration is completed, the piece must again be burned easily in a muffled kiln, prior to glazing. The glaze should be comparatively easily fusible, and preferably of slightly yellow tinge, and as inert as practicable with respect to affecting underglaze colours.

Yet, probably, though the foregoing has been the usual mode of glazing with lead glazes, better burning would give the products greater permanence; and if the colours were more skilfully prepared and lead-free glazes used, specially compounded with a view to being negative in action upon colours, it is quite possible equally rich soft effects would result collaterally with more durable ware; this, indeed, appears to have been accomplished by French *grès* ceramists. It is all a question of persevering research; and those who take the trouble to try to discover the necessary superior colours and colour-inert glazes are very likely to succeed.

When it is desired to paint the glaze upon the ware, in preference to dipping or immersion, first prepare some glaze considerably diluted with water until very thin indeed; brush this thinly over the work, so as to fill up the pores, then afterwards apply the glaze as desired, thicker or thinner according to effects desired over certain colours.

Large subjects may be distributed over large surfaces, for hearths, panels, etc., by applying various portions of the picture or design to separate tiles or slabs, the whole being eventually arranged in order and formed into a single piece, or at least several large pieces, by "slabbing," *i.e.*, carefully cementing them upon slate, after each piece has been finished and fired separately.

When very thickly raised slip-decoration is desired, a portion of plaster of Paris may advantageously be mixed in the slips.

In preparing white slips, oxide of tin naturally suggests itself as an ingredient, but this must be used cautiously, if used at all, because of its tendency to cause the slips to curl off uncalcareous bodies during burning; in fact, as most of the contemporary tile and faience bodies are practically free from lime, and as such beautifully white china-clay and ball-clay and calcined flint are now available, the use of oxide of tin appears unnecessary and wasteful.

Most of the slips are better if mellowed or aged for a few weeks before use; but this must not be continued too long, as the slips may then become so fine as to induce curling off, for mechanical conditions are found to be powerful factors, for better or for worse, in the results of many ceramic processes.

Mr. Sparkes' description of the "impasto" decoration in vogue at Lambeth in 1880 leads to the inference that it is very similar to that known as "barbotine" in Staffordshire. For instance, he says of "impasto":—"The colour is applied to the raw clay; it is, further, so thickened by the vehicle by

which it is incorporated that it models the form as well as paints it. The small amount of relief that is thus given the ornament—coloured as it is—adds to the apparent reality of the thing depicted, and is no doubt an additional power in the hands of the artist; it is also a snare, inasmuch as the treatment of this principle involves a knowledge of modelling, to some extent at least, and without some acquaintance with practice of light and shade it is quite possible to produce a design devoid of effect. . . . . The command over the texture as well as the tint of the background is also a point to be noted, as the application of paint, which has considerable opacity of substance, gives a quality that is never reached by half-transparent films. . . . .

"*Impasto* painting, therefore, has all the advantage that opaque *tempera* or oil-painting possesses; it reflects light from its surface. The opportunity this raised or *impasto* work gives for a second colouring with underglaze colours is to be remarked, as rendering the work of art capable of taking a refinement of finish in detail on the surface prepared for it in relief." (*Jour. Soc. Arts*, 12th March 1880, p. 353.)

In his *Cantor Lecture* on Mosaic, Mr. C. Harrison Townsend, F.R.I.B.A., seems to translate the Italian *impasto* into the English "coloured paste," so that practically, and except for specially attached meanings, it would appear correct to include *impasto* work in barbotine rather than in *pâte-sur-pâte*.

RECIPES FOR DECORATIVE SLIPS.

No. 1.—White Slip (for biscuit-wares).

1 lb. best ball-clay. 3 „ „ china-clay. 3 „ ground calcined flint. ½ „ plaster of Paris.	Soak in about 1½ gallons of clean water for two days, then blunge into a creamy slip, pass through a lawn, and age fourteen days.

No. 2.—White Slip (for biscuit-wares).

1¾ lbs. ball-clay. 1 „ china-clay. 3 „ ground calcined flint. 1½ „ plaster of Paris.	Soak in sufficient water to form a creamy slip, pass through lawn, and age seven days.

No. 3.—White Slip (for biscuit-wares).

4 lbs. ball-clay. 4 „ china-clay. 4 „ china-stone. 8 „ ground felspar.	Soak in 4 gallons of water for two days, then blunge into a slip, pass through lawn, and age fourteen days.

No. 4.—White Slip (for plastic wares).

21 lbs. blue ball-clay. 15 „ china-clay. 13½ „ ground calcined flint. 4½ „ „ china-stone.	Soak in 11 gallons of water for three days, then blunge into slip and sieve through a 90^h mesh brass-wire sieve, and age one month.

No. 5.—White Slip.

4 pints ball-clay slip at 24 ozs. to pint. 2 „ china-clay „ „ 26 „ 2 „ slop flint „ 32 „ 1 „ „ stone „ 32 „	Mix together, lawn, and age fourteen days.

No. 6.—White Slip.

12 lbs. ground china-stone. 4 „ china-clay. 4 „ ground flint. 4 „ „ pitchers. 4 „ ball-clay. 1 „ whitening.	Soak in 5 gallons of water two days, then pass through lawn about 90^h mesh, and age fourteen days.

No. 7.—White Jasper Slip.

4 lbs. ball-clay. 3 „ china-clay. 2 „ ground calcined flint. 4 „ „ Cornish-stone. 8 „ „ barytes. 2 „ „ soda-lime glass. ½ „ plaster of Paris.	Soak in water two days, then sieve through 90^h mesh, and age two days.

No. 8.—White Slip.

2 lbs. ball-clay. 8 „ china-clay. 6 „ ground flint. 4 „ „ stone.	Treat as No. 7.

No. 9.—White Vitreous or Stoneware Slip.

10 pints ball-clay slip at 24 ozs. to pint. 4 „ china-clay „ „ 26 „ 4 „ slop flint „ 32 „ 14 „ „ stone „ 32 „	Intimately mixed together, sieved, and aged.

No. 10.—Cream-Tint Slip (for plastic work).

12 lbs.	superior cane marl, weathered.	Soak in water for three days, then make into slip, sieve through 100^{h} mesh brass-wire sieve, or a 14^{s} silk lawn, and age one month.
4 „	blue ball-clay.	
4 „	strong china-clay.	
2½ „	ground calcined flint.	
2½ „	„ china-stone.	

No. 11.—Cane-Buff Slip (for plastic or biscuit).

8 lbs.	stained ivory ball-clay.	Treat as No. 10.
8 „	siliceous cane clay (Derbyshire).	
8 „	ground white biscuit pitchers.	

No. 12.—Orange-Buff Slip (for plastic or biscuit).

8 lbs.	siliceous yellow clay (Dorset).	Treat as No. 10.
2 „	superior cane marl, weathered.	
½ „	ground china-stone.	

No. 13.—Yellow Slip (for biscuit).

9 lbs.	No. 6 white slip.	Treat as No. 10.
1 „	yellow rutile, ground.	

No. 14.—Drab or Khaki.

5 lbs.	No. 6 white slip (dried).	Soak in water, lawn, and age two days.
¼ „	ground grey oxide of nickel.	

No. 15.—Grey Slip.

9¾ lbs.	No. 1 white slip (dried).	Soak in water, lawn, and age two days.
¼ „	ground "bulldog" furnace refuse.	

No. 16.—Light Green Slip.

5 lbs.	No 2 white slip (dried).	Soak in water, lawn, and age two days.
3 „	Victoria green U.G. colour.	
1 „	ground leadless glaze.	

No. 17.—Yellow-Green Slip (a suggestion).

1 part No. 16 light green slip.
1 „ No. 13 yellow slip.

No. 18.—Olive-Green Slip.

1 lb. ball-clay. 2 „ felspar. 1 „ green oxide of chromium. $\frac{1}{4}$ „ alum.	Soak two days in water, lawn, age ten days.

No. 19.—Bronze-Green Slip.

4 lbs. No. 7 white slip (dried). 2 „ green oxide of chrome. $\frac{1}{4}$ „ alum.	Soak in water one day, lawn, age two days.

No. 20.—Azure-Blue Slip.

(See *Pottery, Brick, and Tile Manuf. Register*, August 1903.)

Base Colour.

$3\frac{1}{4}$ lbs. oxide of zinc. $2\frac{1}{4}$ „ ground flint. $\frac{1}{2}$ „ oxide of cobalt.	Mixed and calcined at 1500° F., and ground.

Mixture.

22 pints white earthenware slip at 26 ozs. to pint.
1 „ base colour, ground, „ 30 „
$\frac{1}{12}$ „ earthenware glaze.

No. 21.—Cambridge-Blue Slip.

4 lbs. No. 6 white slip (dried). $\frac{1}{4}$ „ blue body-stain (50 per cent. cobalt oxide).	Soak in water one day, mix, lawn, and age one day.

No. 22.—Light Brown Slip.

8 lbs. No. 6 white slip (dried). 1 „ rutile, ground. 1 „ soda-ash. $\frac{1}{2}$ „ red oxide of iron.	Treat as No. 21.

No. 23.—Purple-Brown Slip.

$8\frac{1}{2}$ lbs. No. 6 white slip (dried). $1\frac{1}{2}$ „ red oxide of iron.	Treat as No. 21.

No. 24.—Brown Dip.

9 lbs. red clay or marl. 1 „ ground common ironstone.	Treat as No. 21.

NO. 25.—PINK SLIP. (See *P., B., and T. Regr.*, July 1903.)

8 quarts	ball-clay slip	at 24 ozs. to pint.	
3 „	slop flint	„ 31	„
2 „	slop whitening	„ 30	„
2 „	slop felspar	„ 34	„
$\frac{1}{2}$ „	slop U.G. pink	„ 28	„

NO. 26.—SALMON-PINK SLIP.

8 lbs. No. 1 or No. 8 white slip (dried).
$\frac{1}{2}$ „ water-ground Japanese red stain.
} Soak in water two days, sieve, age one day.

NO. 27.—SKY-BLUE SLIP.

72 lbs. No. 3 white slip (dried).
$\frac{1}{4}$ „ blue stain (as under).
$\frac{1}{8}$ „ black oxide of copper, ground.
} Soak in water two days, sieve, age one day.

Blue Stain.

8 lbs. zinc oxide, 4 lbs. cobalt oxide,
2 „ felspar, 2 „ flint.
} Mixed, calcined, and ground.

NO. 28.—MATT-BLUE SLIP.

8 lbs. U.G. matt-blue colour.
8 „ No. 1 white slip (dried).
1 „ white oxide of tin.
1 „ alum.
} Treat as No. 27.

NO. 29.—BLUE SLIP (a suggestion).

13 lbs. No. 3 white slip (dried).
2 „ ground calcined flint.
8 ozs. oxide of zinc, ground.
2 „ cobalt blue.
} Treat as No. 27.

Pâte-sur-Pâte.—An English ceramic artist once, when asked to distinguish or differentiate concisely between barbotine and *pâte-sur-pâte*, replied :—"Barbotine may be described as painting clay on clay, and *pâte-sur-pâte* as modelling clay on clay." Such a very terse definition, however, sacrifices too much to brevity, and omits mention of the opacity of the one and the cameo-like translucence so charming in the other.

Monsieur Solon, the eminent exponent of this art, has explained that the notion of this new decoration on porcelain, namely, the artistic application of white reliefs upon coloured grounds, was not derived from Josiah Wedgwood's

jasper ware, but from a Chinese vase in the museum at Sèvres; and that M. Riocreux, who was then curator, so much admired the contrasts formed by the celadon ground of the vase in question, and the thick white flowers upon it, that he induced a modeller to make some trials with a view to producing something similar at Sèvres. In the attempt it appears to have been overlooked that the Chinese had really put in the celadon field by neatly applying a green-coloured glaze between the raised parts, and that it did not pass under the reliefs as was at first supposed. This misconception resulted in a happier effect than slavish imitation ever could have yielded, and thus the French work proved to possess superior charms to that of the Chinese. (*Studio*, January 1894.)

Edouard Garnier assigns the invention of the French process to M. Louis Robert, chief of the painters' workshops at Sèvres, who in 1870 became director. Garnier considers it a direct result of Salvétat's researches for colours that would bear the hard-porcelain fire. He tells us that trials were begun soon after 1850, and that in 1862 a series of little vases decorated with white paste on coloured ground were exhibited in London, and were highly appreciated; those same specimens were afterwards placed in the museum at Sèvres. Garnier mentions many initial troubles in firing the early pieces; the paste rose in flakes, shrank, or scaled off in a most disappointing manner, the labour of months in the workshops being destroyed in a few hours in the kiln. But the persistence of the learned Regnault, and the indefatigable perseverance of Salvétat, gradually enabled them to acquire some fundamental principles that diminished the losses sufficiently to secure practical success. (*Jour. Soc. Arts*, 22nd February 1889.)

It is not incumbent upon us to attempt to reconcile or co-ordinate these two versions of the early beginnings of *pâte-sur-pâte*; both probably correctly record matters that contributed to the final result.

From the *Cantor Lectures* on Japanese Art Industries, by Ernest Hart, D.C.L., it would appear that the Japanese also derived the *motif* from China.

Whatever were the incidents of its inception and perfecting, there is at least no necessity to hunt far for an authoritative description of the process; for the eminent French artist, who, so far as England is concerned, created and christened this particular style of decoration, has generously given the world a detailed explanation of it all in the *Studio*, vol. ii. No. 10, January 1894.

Monsieur Louis Mark Solon writes:—"May a craftsman more accustomed to ply the china tools than the pen be excused if he venture to jot down in his own words a few notes upon a decorative process he has practised for thirty-five years, and which he hopes to continue to practise as long as he is spared to work? . . . ." After describing his early experiences as an artist in Paris, he continues:—

"M. V. Regnault, the world-famed chemist, was then chief adminis-

trator. The process of decoration in *pâte-sur-pâte* was just on its trial, and M. Regnault thought that my small abilities might be turned in that direction. . . . . At the Exhibition of the Union centrale des Arts appliqués à l'Industrie in 1865, I exhibited for the first time a large series of plaques in *pâte-sur-pâte*. M. Regnault, who wrote the official report, pointed out the difference existing between the methods I had followed . . . . and the regular process in use at the establishment over which he presided. . . . . He requested me to decorate a large vase in my own way, to go with the contribution of the Imperial factory to the International Exhibition, 1867. The outbreak of the Franco-Prussian War put an end to my connection with Sèvres, and upset all my plans. . . . . At this juncture my friend V. Galland, the well-known painter, proposed that I should accompany him to England. . . . . I eagerly seized the opportunity thus offered to me to end the embarrassment of my perplexing situation. The goal of my journey presented itself at once to my mind. Minton's factory, the name which stood foremost . . . . was the place I felt confident I should find permanent employment. My previsions did not betray me; the day after my arrival at Stoke-upon-Trent I was at work doing my preliminary trials, having been most graciously welcomed by Mr. C. M. Campbell, at that time head of the firm. . . . . The name of *pâte-sur-pâte* (body upon body) always seemed to me most appropriate to the process, and I adopted it, although at the manufactory of Sèvres it was soon replaced by various other terms, such as *pâte rapportée*, *pâte d'application*, used ever since.

"It may not be inopportune, however, if I point out the difference existing between this process and a few others which may be thought akin to it in their results. The Wedgwood jasper ware, for instance, although offering likewise white reliefs on coloured grounds, is . . . . produced by mechanical means. . . . . It may be multiplied to an unlimited number of copies; a careful workman is equal to the task.

"A *pâte-sur-pâte* bas-relief, on the contrary, is always an original; a repetition of it could only be made by the artist who has executed the first one. In Limoges enamels, sometimes mentioned as presenting some analogy, the difference is still better marked, for in this case effect is not obtained by gradation of reliefs, but rather of lights and shades. . . . .

"*Pâte-sur-pâte* decoration may be executed upon any semi-vitrifiable body, but the material used for the applied parts must always be of the same nature as the mass of which the piece itself is formed. The hard-porcelain paste is, for density and fineness of substance, superior to any other; it is the one employed in France and Germany. But as very few metallic oxides can stand the high degree of heat to which it has to be submitted, the scale of available colours is consequently very limited.

"With the body in use at Messrs. Minton's, on the contrary, a great variety of colours can be obtained. It is a sort of Parian; the elements entering

into its composition are the same as those used for hard porcelain, but mixed in different proportions. Most complicated kinds of forms can be produced in that body: the biscuit is at first thoroughly fired, and during this operation the pieces can be properly supported in all their weak points; the glazing is subsequently proceeded with at a much lower temperature. It is not so with hard porcelain; the highest degree of heat has to be reached to bring the glaze into fusion. Supports cannot be used, as they would stick to the piece, and therefore only a certain class of shapes can be attempted. . . .

"Simple as the method of proceeding has now become, one must not imagine that the difficulties of the first experiments were easily mastered. The white clay, thickly applied upon a dry surface, would not adhere to the ground, but insisted on curling up or falling off in the firing. To guard against such accidents, vases were kept in the wet state as long as the work of decoration was being prosecuted. . . . This was an unhandy and almost impracticable method. . . . Since then, and although the method has long been abandoned, the description has been reproduced in many other works. . . .

"The present mode of working does not, happily, offer any such impediments. It may be described in a few words. . . . A vase or a plaque of unbaked clay can easily be obtained. . . . By passing it through the *hardening-kiln* it becomes hard enough to be handled with facility. The contraction it will undergo in firing will be about one-seventh of its primitive size; the clay employed upon it must therefore also be unbaked clay, to allow of its following the general contraction of the whole piece.

"Either the vase or plaque is made throughout of coloured clay, or the coloured clay is merely laid as a ground upon the white surface; this is the safest way to obtain a very dark tint. To ensure success an important precaution has to be taken when proceeding with the work. The clay, diluted with water to the consistence of a batter, or, as it is called, made into 'slip,' is laid on by thin washes with a paint-brush, one wash being followed by another until the required thickness is obtained. If due care is taken never to apply a fresh coat but when the preceding one is perfectly dry, the work will never crack or peel off. This is the only technical rule absolutely necessary to observe. All else that remains depends more on the artistic feeling of the operation than on professional secrets.

"Brush-work alone provides a rough preparation in which the thickness of the various parts of the design must already be indicated. It forms a sketchy ground-work, the lumpy surface of which has to be scraped, smoothed, carved, and incised by means of sharp iron chisels, called repairing tools, just in the same way as a sculptor proceeds when dealing with other materials.

"If it happens that more strength is needed in some places, the brush,

dipped in 'slip,' will supply additional substance, and its use may constantly be associated with the use of the chasing tools. . . .

"On happy combinations of transparency and opacity depends, of course, the ultimate result, but in that respect much has to be left to the hazards of firing. Even long experience cannot enable us to foresee all possible accidents. As long as the work is in progress all is equally opaque, but when it has been passed through the oven, and undergone partial vitrification, then only do we become aware of the fact if a deplorable miscalculation has been made.

"The body is coloured by adding 1 to 10 per cent. of metallic oxides incorporated in the paste by thorough grinding. Oxide of cobalt gives the blues; oxides of chrome and chromates supply the greens, the browns, the black, and the pinks; iron affords the dark yellows and light browns. A stone naturally coloured by iron of a bright brick-red colour, found in the South of France . . . . preserves in the oven the intensity of its tint. Titanium gives the bright yellows and light warm browns . . . . nickel gives the greens and the browns. . . . .

"All the above pigments may, of course, be mixed together and produce a great variety of tints. . . . .

"Although the *pâte-sur-pâte* process partakes of the character of both painting and modelling, to be really effective it must differ entirely in its treatment. The work, only slightly raised upon the ground, is not to be likened to a bas-relief; lacking the resource of shading, it cannot be compared to an enamel painting. Well-devised transparencies may assist in establishing the distances between the respective parts of the picture; but, besides a good distribution of thin and thick reliefs, it is most important that all details should be sharply accentuated, both with incised lines and neatly raised touches of 'slip.' This touching-up must be exaggerated to a degree which, upon any other material, would seem to go beyond all limits of permitted dryness of workmanship. It is, however, the only way of securing clearness and brilliancy to the details when all is baked in a thick coating of transparent glaze." (*The Studio*, vol. ii. No. 10, January 1894. Reprinted by special permission.)

In the foregoing lucid explanation M. Solon indicates that the body he has made use of in England is a sort of parian; for this reason a number of recipes for "parian" bodies, and also for "stone" bodies, "jasper" bodies, and "bone-china" bodies are appended, which, when selected and corrected to suit the individval requirements of each manufacturer and each special purpose, and a suitable glaze selected and adapted to the body, may be found serviceable.

All *pâte-sur-pâte* wares are glazed to heighten the artistic effect and to complete the style; hence, whatever body is chosen should be of such a nature

as to bear glaze well. This is not an altogether simple matter with "parian" bodies, and preliminary trials should always be made of the body and slips and glazes intended to be used.

RECIPES FOR PARIAN BODIES.

No. 1.—FRITTED PARIAN BODY.

Intimately mix 40 lbs. ground china-stone and 20 lbs. soda, and frit the compound in flinted saggars in the biscuit oven.

Then grind together:—

7 lbs. of the above frit.
1 lb. Cornish china-stone.

Then for casting prepare the following mixture:—

35 ozs. ground frit-composition as above.
48 „ ground Cornish china-stone.
22 „ blue ball-clay.
2 „ soda.

The soda is used to assist the casting, and a little lime-water added to thicken the compound and prevent settling. The slips should be kept warm when casting.

No. 2.—FRITTED PARIAN BODY.

Frit.

100 lbs.	Lynn sand.	Boil with a little water, mix to a paste, and calcine in earthenware biscuit oven.
60 „	felspar.	
20 „	pearlashes.	

Body.

240 lbs.	china-clay, strong.	Grind together
120 „	calcined felspar.	
120 „	uncalcined felspar.	
80 „	frit, as above.	
40 „	glass.	

No. 3.—FRITTED PARIAN BODY.

Frit.

2 lbs. Lynn sand.
1 „ borax.

Body.

6 lbs. ground Cornish china-stone.
3 „ china-clay (kaolin).
2 „ frit, as above.
2 „ glass.
1 „ ground calcined flint.
1 „ blue ball-clay.

NO. 4.—PARIAN BODY.

5 lbs. ground felspar.
5 „ china-clay (kaolin).

NO. 5.—PARIAN BODY.

5 lbs. ground felspar.
3 „ china-clay (kaolin).
½ „ ball-clay.

NO. 6.—PARIAN BODY.

14 lbs. calcined felspar } ground together.
11 „ china-clay (kaolin) }

NO. 7.—PARIAN BODY (for brackets).

6 lbs. felspar } ground together.
2 „ white ball-clay }
2 „ china-clay }
1 „ ground flint }

NO. 8.—PARIAN BODY.

6 lbs. felspar } ground together.
4 „ best china-clay }
2 „ white ball-clay }
3 „ frit, as in No. 2 body }
1 „ glass }

NO. 9.—BLUE PARIAN BODY.

7 lbs. dry parian body } ground together.
1 oz. dry cobalt blue }

NO. 10.—MATT BLUE DIP (for parian).

3¼ lbs. parian body } ground together.
1 „ Saxon-blue stain }

No. 11.—Parian Stopping for Biscuit.

5 lbs.	parian body	ground.
1 „	felspar	

Parian Stopping for Glost.

6 lbs.	parian body	mixed.
4 „	china glaze	

RECIPES FOR VITREOUS STONE BODIES.

No. 1.—Pink Stone Body.

10 lbs. ground Cornish china-stone.
7 „ blue ball-clay (Dorset).
6 „ underglaze pink colour.
3 „ whitening (lime carbonate).
1 „ white oxide of tin.

No. 2.—White Stone Body.

340 lbs.	ground Cornish china-stone.	Soak in water three days, then blunge into slip and sieve.
175 „	blue ball-clay.	
45 „	china-clay (kaolin).	
15 „	ground calcined flint.	
19 ozs.	slop blue body-stain at 23 ozs. to pint.	

No. 3.—Drab Stone Body.

340 lbs.	ground Cornish china-stone.	Soak in water three days, blunge into slip, and sieve.
175 „	blue ball-clay.	
45 „	china-clay (kaolin).	
15 „	ground calcined flint.	
10 „	„ nickel oxide.	

No. 4.—Sage Stone Body.

340 lbs.	ground Cornish china-stone.	Soak in water three days, blunge, and sieve.
175 „	blue ball-clay.	
45 „	china-clay (kaolin).	
15 „	ground calcined flint.	
40 „	slop sage stain (as below) at 30 ozs. to pint.	

Sage Stain.

2 lbs. oxide zinc, 2 lbs. whitening, 3 lbs. flint, 5 lbs. borax, 2 lbs. soda phosphate, 3 lbs. chrome green, 2 lbs. cobalt blue.	Calcine in thin layers in glost oven. Then grind.

No. 5.—Turquoise Stone Body.

13 lbs.	white stone body.	Soak in water, intimately mix, and sieve.
8 ozs.	oxide of zinc.	
2 „	blue (cobalt).	

No. 6.—Dove Stone Body.

450 lbs. ground Cornish china-stone.
225 „ blue ball-clay.
15 „ ground barytes.
4½ „ „ zaffre blue.
9 „ „ manganese.

RECIPES FOR BONE-CHINA BODIES.

No. 1.—China Body.

420 lbs.	ground calcined bone.	Soak in water for one day, blunge, and sieve.
250 „	„ Cornish china-stone.	
230 „	best china-clay (kaolin).	
30 „	ground calcined flint.	
6 ozs.	blue stain at 23 ozs. to pint.	

No. 2.—China Body.

420 lbs.	ground calcined bone.	Soak in water for one day, blunge, and sieve.
260 „	„ Cornish china-stone.	
260 „	best china-clay (kaolin).	

No. 3.—China Body.

400 lbs.	ground calcined bone.	Soak in water three days, blunge, and sieve.
300 „	„ Cornish china-stone.	
150 „	best china-clay (kaolin).	
100 „	blue ball-clay.	
4 ozs.	blue stain at 23 ozs. to pint.	

Mr. John C. L. Sparkes, Principal of the Royal College of Art, South Kensington, when speaking in 1880 on the development of fine-art pottery manufacture at Lambeth, referred to *pâte-sur-pâte*. He remarked:—"By far the most important introduction has been a method of decoration . . . . called *pâte-sur-pâte*. It is, perhaps, more correctly so named than the French ware which bears the same designation. The term *pâte* in French has been translated literally as paste, and hence the rather unmeaning description of china as hard and soft paste of some writers; but *pâte* means body, and

pâte-sur-pâte describes that method of decorating one body with another of a different tint. This very beautiful material was produced to show at the Paris Exhibition of 1878, and has been worked since with great success. To paint with earthy pigment requires great decision of hand and accuracy, and as each touch with the brush delivers the exact amount needed for the leaflet or digitation of the foliage used, it requires much practice and unerring certainty in planting the material on the ware firmly and in the right place. The peculiarity of the method has produced a certain conventionality in the decoration, and a crisp-leaved sort of parsley-fern pattern seems to be the one mostly adopted. . . . . There are eighteen colours and tints which can now be used in these ways. . . . . The difficulties here overcome were great and numerous, but a very accurate adjustment of flux and pigment has been worked out, so that the opaque portions partly burn away and become semi-transparent, showing the ground through. One great trouble was to obtain adhesion between the body and the colour ; this, however, is now successfully overcome, and I ask your attention to these beautiful examples of stoneware burnt in the open kiln and glazed with salt. This is absolutely new in the potter's art, and is a true example of the *pâte-sur-pâte* principle, inasmuch as it is not enamel, but body, that is the basis of the decorating material." (*Jour. Soc. Arts*, 12th March 1880, p. 347.)

Sgraffito.—The terms "*Sgraffito*" (scratched) and "*Sgraffiatūra*" (method or result of decoration by scratching) are evidently derived from the Italian verb "*graffio*" (to scratch). They are, however, now used by English-speaking peoples to denote a special mode of ornamentation implying something more than simple incisions or excisions. The scratching is understood to be done through a surface layer of one colour to an undercoat or body of another colour, and so as to remove portions of the upper surface sufficiently to expose the lower one in contrast, thus accentuating the design. Further, these excisions must be of such a nature as to artistically express a definite ornamental composition or design.

One common material for *sgraffito*-work is a sort of coloured cement or plaster or stucco, ably described by Mr. Heywood Sumner at the Society of Arts, 10th February 1891, and later by Mr. A. L. Baldry in *Modern Mural Decoration*.

Then a large portion of the marble pavement of Siena Cathedral is also referred to as "*pavimento a graffito*," but this is not quite the kind of work to which the term is usually applied in England, the incisions being filled up level with a hard-setting coloured composition in contrast with the colour of the marble, more of the nature of inlaying.

The application of this style of ornamentation to ceramic products has been described by Fortnum in the *Catalogue of Maiolica in the Ashmolean Museum, Oxford*; by W. Burton, F.C.S., in his *Cantor Lectures*, "Material and

Design in Pottery"; and by J. C. L. Sparkes in connection with Lambeth stoneware. (See *Jour. Soc. Arts*, 12th March 1880.)

But the only mention of its use in decorative-tile work and faience, as far as the writer's information goes, is in Jewitt's *Ceramic Art of Great Britain*, wherein it is stated that "*sgrafito*" was practised by Messrs Maw & Co., of Benthall (that would be prior to 1878).

In the manufacture of decorative tiles and faience, simple incision, as a method of ornamentation, may be said to be very largely even though mechanically represented in the great series of impressed tiles so closely associated with the embossed tiles; when these have been glazed by means of easily-flowing coloured glazes or transparent enamels, an effect somewhat resembling very much softened *sgraffiatùra* results, notwithstanding its essentially different nature.

But true ceramic *sgraffito*-work produced by artistic excision of an engobe applied upon the surface of a tile would be costly, and would present technical difficulties, not insurmountable, perhaps, but certainly troublesome; for if a slip was applied to the whole face of a dust-made tile in an unfired state, the face would probably often be injured. And if a thin layer of dust was applied after the manner of encaustic-inlaid dust-tile work, the subsequent excision being effected through a granular engobe would probably result in ragged outlines. In the case of plastic-made tiles and faience, the application of engobes would be simple except for the disposition to warping or buckling, and to overcome this a previous biscuit-firing might have to be resorted to.

Although ceramic *sgraffiatùra* would be durable, there would be the objection of jointings between the several parts, and of the work not being executed *in situ*, so that existing conditions would perhaps not be always accurately gauged. Whether such work has been attempted is apparently somewhat uncertain. Mr. Hugh Stannus, F.R.I.B.A., of Clapham, assures the writer that he is not acquainted with any example of *sgraffito*-work in keramics, except in vases and plates; and that he never saw any keramic *sgraffiatùra* by the Della Robbia family. He also expresses the opinion that keramic *sgraffiatùra* would not hold its own against brush-work, such as the panels now painted upon series of 6-inch by 6-inch tiles built up together, which after painting are taken apart to be baked and glazed (*i.e.*, barbotine and biscuit-painting).

Possibly when some little change is desired from the now fashionable mosaic, enamelled, and underglaze-painted tiles, *sgraffito* tiles may have a day. Or for exterior ornamentation the new stoneware enamelled terracotta may possibly lend itself to this treatment.

A suitable body may be composed by mixing together equal quantities of weathered red marl and weathered cane marl, soaking the mixture in water, then blunging into slip, sieving, and either boiling to a plastic state on a slip kiln or pressing it in a filter-press.

Whatever clays or ingredients are used to prepare the body from, they must not be excessively siliceous, otherwise the engobes or slips will peel off. The opposite condition is, of course, equally to be avoided for other reasons. When the process is used for *stoneware*, other bodies and engobes would be needed.

RECIPES FOR DIPS OR ENGOBES FOR SGRAFFITO FAIENCE.

No. 1.—Sgraffito White Dip.

$5\frac{1}{4}$ lbs. blue ball-clay.		Soak in water three days, with or without a little soda, blunge into slip, sieve through 100th mesh sieve, and age for one month.
$3\frac{3}{4}$ „ china-clay (kaolin).		
$3\frac{3}{8}$ „ ground calcined flint.		
$1\frac{1}{8}$ „ „ china-stone.		

No. 2.—Sgraffito White Dip.

8 lbs. black ball-clay (Devon).	Treat as No. 1.
8 „ china-clay (kaolin).	
$2\frac{1}{2}$ „ ground calcined flint.	
$2\frac{1}{2}$ „ „ china-stone.	

No. 3.—Sgraffito Cream-White Dip.

10 lbs. black ball-clay (Dorset).	Treat as No. 1.
11 „ ground calcined flint.	
1 „ china-clay (kaolin).	

No. 4.—Sgraffito Buff Dip.

4 lbs. ivory ball-clay, stained.	Treat as No. 1.
4 „ siliceous cane clay (Derbyshire).	
4 „ ground white earthenware pitchers.	

Biscuit-Painting.—The artistic application of a full palette of pure ceramic underglaze colours, foreshadowed in late mediæval Persian decorative ceramics, has in our time been brought to a very high level of merit.

And if, perhaps, the pictorial effects produced are often merely copies of the work of superior artists on canvas, this fact does not necessarily detract from the merit of the process *per se*, which, owing to the colours being beneath the glaze, possesses the advantage of permanence.

Slabs or plaques, either dust-made or plastic-made, are so decorated ; and when very large areas have to be attempted, groups of biscuit tiles are placed together on the easel and painted as one piece, and afterwards are separated

for glazing and burning; these are recomposed when applied to the wall, hearth, or other position for which the work is intended.

The artist first sketches in the design in pencil, and previous to applying the necessary colours the design is often outlined in a suitable dark colour. The colours may be mixed in a medium consisting of either gum and water, or turpentine and fat oil (the resinous residue after considerable evaporation of the turpentine). If the colours are mixed in the latter medium, the tiles or slabs after decoration will require to be slightly burned previous to glazing. If mixed with gum and water, the glazing can be proceeded with immediately the colours are dry.

FIG. 255.—Painting a plaque.

The glaze may be applied to the tile-faces either by brushes or by dipping; the former method is often best, because it enables glaze to be laid on more thickly where it is required to specially develop certain colours.

Fig. 256 represents a suitable muffled kiln for the purpose, having two firing-mouths, and a shed at the side serving the double purpose of protecting the muffle wicket or entrance, and of providing storage-room for quarries, props, and utensils.

Baldry, in his *Modern Mural Decoration*, remarks:—"The tendency now is in the direction of a more pictorial manner of dealing with wall-tiling. There is a fashion for pictures on ceramic surfaces, and lately the response to this fashion has been very general. Panels and friezes, which are in their strength of colour and their range of tones carried quite as far as paintings on canvas, have become common decorative devices. They are constantly to be met with in buildings where adornments of a permanent kind are desired, and up to a certain point they may be said to justify themselves. Their chief fault is a thinness of colour quality which makes them look mechanical, and at times commonplace; it is most evident when very

ambitious compositions requiring sensitive handling have been attempted, because the process of firing destroys some of the charm of the artist's touch. In designs which have been judiciously conventionalised this loss of individuality in the handling is, however, not so perceptible. . . . . Indeed, if a number of the best examples of modern tilework are examined, the impression that the art lends itself to a very wide variety of treatment is irresistible. There are plainly many ways in which it will serve as an adjunct to architecture." (*Modern Mural Decoration*, p. 116, Newnes.)

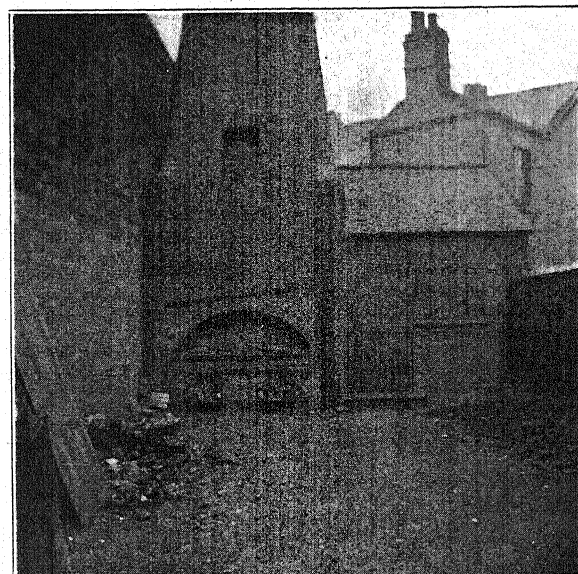


FIG. 256.—Muffled kiln for tiles.

In the remarkably fine exhibit of Messrs. Maw & Co.'s manufactures at the Chicago Exhibition of 1893, all the painted work throughout the exhibit was hand-painted underglaze. This included richly painted panels in the ecclesiastical department, and the lunettes and spandrels of the entablature.

FIG. 257.—The Bay of Naples. (W.N.F. Coll.)

This process may be applied on coloured bodies, such as cream-tinted, olive - tinted, turquoise-tinted tiles, thus forming grounds upon which the painting is superimposed and afterwards covered with a protective glaze. Local views or tile-pictures of any kind are within the scope of this versatile process, and the tiles may, of course, be used in any appropriate situation.

Such work is claimed to be "beyond the reach of all but actual violence."

All leading firms undertake this work. Messrs. Carter & Co., of Poole, by whose kind permission we are enabled to illustrate tile artists at work (fig. 258) inform the writer that underglaze pictures of this kind are as a rule painted on 6-inch tiles, rarely on 8-inch tiles.

FIG. 258.—Artists at work. ("*Interesting Notes on Ornamental Tile Manufacture*," p. 17. *Carter & Co., Poole.*)

Biscuit-Printing.—The methods of underglaze decoration described in the foregoing notes are each operated by hand, assisted only by the simplest of hand tools. Therein perhaps lies some of the charm of the work; therein, too, is the explanation of those gulfs of difference in merit met with in each style, for so very much depends upon the individual skill of every operative. Biscuit-printing, on the contrary, being mostly a mechanical method of applying reproductions of artistic designs in limitless profusion, there remains no excuse whatever for multiplying anything but the best.

Hypercritical minds have questioned the artistic bearing of the extensive use of mechanical means of decoration, but it must be confessed that reproductions of designs suffused with genuine artistic feeling and skill are more likely to yield permanent pleasure than the hand-painted perpetrations of mediocrity. There is a case in point in the old Delft tiles; so long as they were decorated by clever artists all was well, but when decadence set in the results were pitiably inferior.

The Right Hon. Joseph Chamberlain answers such critics tritely thus:— "We must recognise the necessity for seeking the assistance of machinery and

of all the devices which would bring within the reach of the many, if not the highest works of art, at all events something elevating, and something which might be accepted as a provisional substitute." (*Architect and Contract Reporter*, 15th December 1899.)

That this has been accomplished by printing is evident on every side—books, printed pictures, wall-papers, calicoes, woollens, linens. The enormous output of underglaze printed ceramic ware itself is the most undeniable testimony to its advantages and acceptability. Yet at first even the great Josiah Wedgwood, far-seeing though he was, is said to have discountenanced it, notwithstanding that he eventually made use of it extensively. (See Jewitt's *Life of Wedgwood*, p. 150.)

Ceramic biscuit-printing is an indirect mechanical process effected by means of tissue-paper *transfers*, to which the pattern in one or more colours has been applied from engraved or etched copper-plates or rollers.

In the older process copper-plates are used ; these are rolled and hammered sheets of metallic copper about $\frac{1}{8}$ of an inch thick, and about one or two square feet in area. One side of each plate is "planished," *i.e.*, rubbed smooth and level by means of fine-grained rubbing-stones and water, finished by rubbing the surface with a stick of dense charcoal and water.

Sometimes the plates are faced by an electrical deposit of steel, to impart greater durability and to enable them to receive more finely engraved patterns.

Other requisites for the process are a palette-knife, spud, dabber, bakestone, muller, bosser, finger-leathers, printing-press, press-plank, stove, flannel, colours, oil, papers, size, and brush.

A printer's palette-knife is of the ordinary palette-knife form, only of large size and about 2 inches broad in blade. The *spud* is simply a worn-out palette-knife, broken off short and sharpened to a fine, smooth, square end, for scraping the colour off the copper-plate. A *dabber* is a wooden tool, of conical shape, the apex being replaced by a ball or sphere shape top, and the base simply a flat circular surface about 3 inches diameter. A pottery printer's *bakestone* is a flat disc of iron, 15 inches or so diameter, $\frac{1}{2}$-inch thick, with a smooth upper surface, and having a loop or bow handle projecting horizontally from the rim or edge. Upon this, when warmed, the colours are intimately mixed with the printer's oil. The *muller* is a flat-faced stoneware grinding tool, about 5 inches diameter of face, with a handle projecting from the centre of the back ; this is for grinding the colour into the oil on the heated bakestone. The *bosser* is an oval-shaped cushion of "corduroy" material stuffed with wadding, about 6 inches by 3 inches by 2 inches, with a piece of wood sewn to it along the top or back. This is for "bossing" the engraved copper-plate clean, ready for taking an impression.

Finger-leathers are small pieces of leather to protect the printer's fingers while handling the hot copper-plates.

One would almost have thought that the manipulation of such a crowded quiver of utensils would have left the artist with his brushes and palette as much a victor as David with his sling and stones: but it is not so; pottery printing, encumbered as it is by utensils, is a comparatively effective and economical method of decoration.

The hand-power *printing-press* is a very elementary machine, consisting of two iron rollers 20 inches long and 15 inches diameter or thereabout, fixed in a frame at a convenient height to stand to, and having a handle connected so as to turn the rolls by one movement. Around the upper roller five thicknesses of milled flannel are attached, the joinings being so placed that they do not come on the plate as it travels in and out between the rollers.

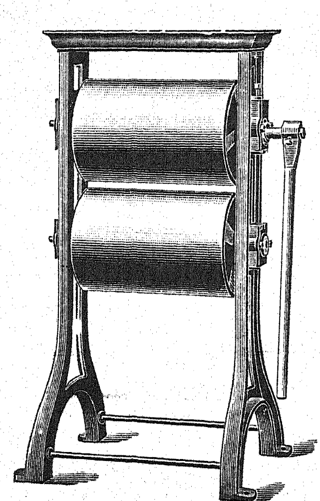


FIG. 259.—Printing press. (*By The Crossley Manufacturing Co., Trenton, N.J., U.S.A.*)

The *press-plank* is a strong iron plate, about 3 feet 4 inches by 1 foot 6 inches, upon which the engraved copper-plate is laid while passing through the rollers, to keep the copper-plate true and free from injury.

A *printer's stove* is merely a sort of large hot-plate heated either by fire or by steam, upon which the copper-plate and colour-bakestone are laid to get heated, the printing being in reality a hot process, with a stiff medium.

The preparation of the *colours* will be described shortly.

The *printer's oil* is a compound of 5 gallons of linseed oil, 1 quart of rape oil, and 2 quarts of spirits of tar, boiled together and skimmed; the boiling, which needs great caution, being continued until the mixture "ropes" well. The *size* is made by boiling together two quarts of water, 1 lb. of soft soap, and 2 ozs. of soda crystals. The *paper*, known as *pottery tissue*, is specially prepared, fine, perfect tissue-paper, manufactured mostly at three paper mills in Staffordshire, viz., Brittain & Son of Hanley and Cheddleton, and Lamb & Son of Newcastle-under-Lyme.

In practice the process naturally divides itself into three principal operations—printing the tissue, cutting up the impressions, transferring it upon the ware. The work is accomplished somewhat as follows:—The tissue-paper is cut into rectangular sheets of the size and shape of the engraved copper-plate to be used, or rather larger than the engraved portion of the copper-plate; the sheets of tissue-paper are placed, two at a time, upon a board, and sized on one side with the special size aforenamed, leaving a corner dry.

A little of the desired colour, in a dry, finely-ground condition, is crushed

in a mortar, and placed upon the bakestone, which should be on the hot stove; when the colour is perfectly dry, sufficient printer's oil is poured on the colour to make it of the consistency of butter, and the colour and oil while hot are intimately mixed and ground together on the bakestone by means of the muller.

Meanwhile the engraved copper-plate should also have been heated by laying it on the stove or hot-plate, and should be hot enough to only bear a rather quick touch of the finger, yet not so hot as to burn the oil. When uniformly hot, both engraved plate and bakestone are placed on the bench, and by means of the palette-knife the warm oiled colour is taken off the warm bakestone and spread upon the engraved portion of the hot copper-plate; then by means of the dabber the colour is thoroughly rubbed into every part of the engraving. Then excess of colour is scraped off the copper-plate by means of the palette-knife and returned to the bakestone. Afterwards the copper-plate is bossed all over with the bosser, so as to clean off every particle of colour not in the engraved pattern.

While still hot the plate is placed upon the iron press-plank, and a wet sheet of sized tissue-paper carefully laid upon the engraving without creases; over this a sheet of flannel may be laid, and the whole passed between the rollers once and drawn back again. After thus pressing, the engraved plate, with the adhering sheet of tissue-paper, is laid upon the hot stove, and as soon as the paper dries it is carefully lifted off the plate, with the colour-impression adhering upon it, and is laid over a rail ready for the cutter; the foregoing process being repeated upon additional sheets of tissue as often as required. The cutter then takes the printed sheets of tissue, cuts off any excess of paper, and separates the sheet into as many parts as the impression needs to suit it to the ware or tiles, and in turn places these parts carefully in a certain order of rotation in readiness for the transferrer.

The transferrer then takes the part of the transfers as required, and in accordance with the pattern lays it carefully, printed side down, upon the faces of the biscuit ware or tiles, pressing the transfer very firmly all over the ware, and finally very forcibly rubbing it on with a flannel rubber slightly lubricated on its surface with soft soap. This done, the ware or tiles, with transfer paper adhering, are placed aside to set.

A few hours later the paper may be soaked and floated off the tile by immersion in water; after which the printed tiles are placed in bungs or heaps, one above the other, separated by small fragments of pitchers; and, after drying, are baked in a muffled kiln, so as to burn away the oil and fit them for receiving the glaze. This burning is called "hardening on." Frequently, after the printing has been done and the paper soaked off, other colours, mixed in a medium of spirits of tar, are painted upon parts to enrich the pattern and make it polychrome; this is called "filling in."

When it is desired to print several colours upon the tile in one pattern, a process is adopted of having several engravings each containing only part of the pattern; these engraved plates are fitted into a kind of folding press-plank, with fine points or pegs projecting from parts between the plates, and on these pegs the papers can be fixed again and again, so as to coincide accurately with the position of the engravings. An engraving being inserted (the colour having been already applied to it), a sheet of paper is put in the apparatus, which is then closed up and the impression taken by passing between the rollers, other sheets being followed on the same engraving and with the same colour, until the desired number of sheets are printed. Then the engraving is removed, and another engraving, with another part of the pattern and with another colour on, is put in the apparatus, and one by one the sheets are carefully fixed in again, guided by the little pegs, and the other colour applied to all the sheets. If a third colour is wanted, another engraving and colour are worked in the same way. When all the colours and pattern have been applied to the tissues and the prints are thus completed, the transferrers then apply them to the biscuit tiles in the manner already described.

It will be obvious that the most accurate possible registration of the several printings on the transfer sheet is necessary to success.

Roller Printing Machines.—When a large number of impressions of any one pattern or of several patterns is required, the transfers may be more economically produced by means of roller printing machines.

Something of the kind was invented and patented in 1831 by John Potts, Richard Oliver, and William Wainwright Potts (patent No. 6162). The abridgment of specification reads:—"An improved method or process of obtaining impressions from engravings in various colours and applying the same to earthenware, porcelain, china, glass. . . . . This consists in employing for the above purpose a cylinder printing machine, such as is generally used by calico printers. . . . . The paper is sized by passing through an arrangement of sizing rollers. The colour-box in the cylinder press is heated by steam into a double bottom. The furnishing roller is preferred not to be covered with flannel. . . . ."

Whether this invention was ever put into practical use is unascertained, but certainly very little was being done with it in Staffordshire between 1870 and 1880.

Mr. George Griffiths, in a paper read at the Higher Grade School, Hanley, 17th January 1903, mentioned another almost forgotten cylinder or roller machine for pottery printing. He said:—"About the year 1860 there was a printing machine in use at what is now known as Baker's Old Works at Fenton. This machine, it is said, was one of two made by George Henry Fourdrinier." In the course of the discussion upon Mr. Griffiths' paper, Mr. Williams

spoke of the use of a machine at the works of Messrs. Baker & Co., Fenton, more than forty years ago. It kept sixteen sets of women at work transferring. It possessed engraved roller, pressure roller, colour-trough and doctor, and was heated with steam. Sized paper was used. The cylinders or rollers were adapted to interchangeable mandrils, and had not the fixed mandrils as in Turner's machine. Forty years ago the manufacture of "granite" ware was introduced, and the large trade of printed ware done by the firm up to that date was gradually given away. Eventually the machine was put aside, as there was not work sufficient to keep it in successful operation. . . . . The patent granted in 1846 to Fourdrinier for this machine was exhibited to the Society complete, with attached seal. (*Trans. N.S.C.S.*, vol. ii. p. 60.)

About 1886 Mr. W. Hales Turner, of Tunstall, invented a roller printing machine, taking out the following patents in connection therewith:—No. 15340 (1886), No. 17160 (1886), No. 120 (1887). The complete specification of No. 15340 (1886) reads as follows:—" Improvements in or relating to machines for printing designs upon paper or other material, especially applicable for the decoration of earthenware, china, glass, tiles, granite, and the like. I, William Hales Turner, of Chell Lodge, Tunstall. . . . . This invention embraces a hollow, heated printing cylinder upon which the color is placed, and against which the strip or band of paper, or other material upon which the design is to be printed, is pressed, such strip or band of paper being pressed against the heated cylinder by another roller around which passes a blanket of india-rubber; or the roller may be faced or covered on its periphery with india-rubber, in which case cold water is occasionally passed through the centre of the roll to prevent it slipping. The color is applied by means of a plate, preferably of copper, heated as required, upon which the color is placed and, if the plate be inclined, slides down to the roller, the plate serving to apply the color, to press it into or on to the cylinder, and to scrape off the surplus." Then follows a minute explanation of the machine, with references to the drawing of it which accompanies the specification. "Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is:—

"(1) In printing machinery, such as described, the combination with the heated printing cylinder C^2 of an india-rubber roller or blanket. . . . .

"(2) . . . . Cooling the roller C^3 by means of water, or other means, to protect it from excessive heat, substantially as described.

"(3) The method of applying the color direct to the printing cylinder by means of a plate or doctor J without the intervention of a roller. . . . .

"(4) The combination with the doctor J of an adjustable balance-weight or weights L, for regulating the pressure of the doctor against the cylinder. . . . .

"(5) The complete method of and apparatus for printing on pottery tissue-

paper for the purpose of 'transferring' in the earthenware and ceramic trades, substantially as specified.—Dated this 20th day of September 1887. WILLIAM HALES TURNER."

Specification No. 17160 (1886) relates to a minor improvement, thus:—"Hitherto the rollers employed have been large in diameter, causing enormous expense in the engraving, but by my invention I reduce the rolls to the smallest practicable diameter. The ordinary rollers consist of a spindle or mandril with a copper or steel face; my improved rollers consist of the mandril only, which I make of the proper metal and engrave upon the mandril itself."

Specification No. 120 (1887) relates to improvements such as sizing the paper in a special manner and heating the colours more highly, and other matters to facilitate rapid printing, with lessened abrasion of the printing surfaces and the doctors or scrapers. Formulæ are given for the preparation of the size and of the oily medium for the colours.

In a pamphlet relating to Turner's machine, issued in 1887 by The Pottery Printing Machine Co., of Tunstall, the possibility of great economies is claimed.

Whether in actual practice over long periods these have been realized or otherwise remains unstated. It is said that one hundred and sixty machines have been made, some giving satisfactory results, while in other instances the machines have been subsequently discarded.

Many interests are affected, and this hesitating development of an invention is not unusual. An American potter recently put the matter in a very trite manner by saying:—"Printing is the only process where we see any trace of evolution, and the roller press is here to stay. The identically same machine was used by calico-printers in the year 1770; so you see it has taken the potters about one hundred and thirty-three years not to invent, but merely to attempt the use of it, and to-day we can only print in one color. We will only hope it will not take another hundred and thirty-three years to print in more than one color." (*Trans. Am. Cer. Soc.*, vol. v. p. 375.)

In 1889 Mr. W. Hales Turner invented another printing machine, which he designated the "monochrome"; but this, the writer understands, has not been taken up by manufacturers of pottery.

Mr. Turner states that eight different types of his printing machine are at work, some of which are used for printing transfers for tile decoration. At one factory two machines work exclusively for this purpose; while at another factory four roller printing machines are in use partly for tiles and partly for other wares. There is, however, independent testimony of the value and success of roller printing machines, and at least three other engineering firms make such machines.

Lithography.—So long ago as A.D. 1848 Jewitt tells us that Collins & Reynolds, of London, who had for years previously been decorative and

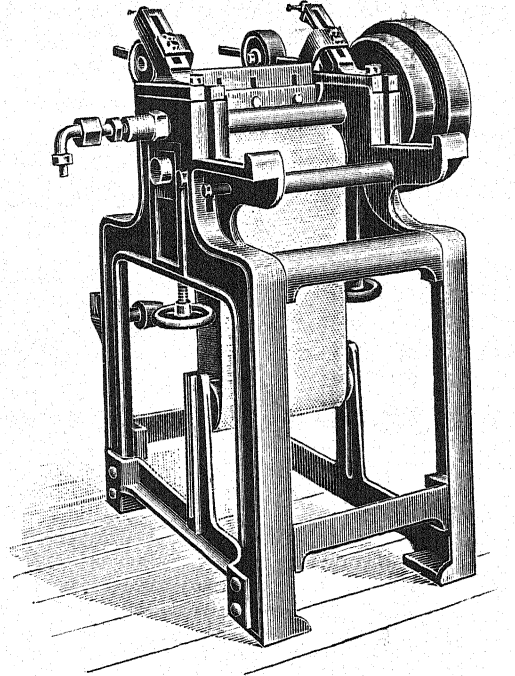


FIG. 260.—Roller printing machine. (*By W. Boulton, Ltd., Burslem.*)

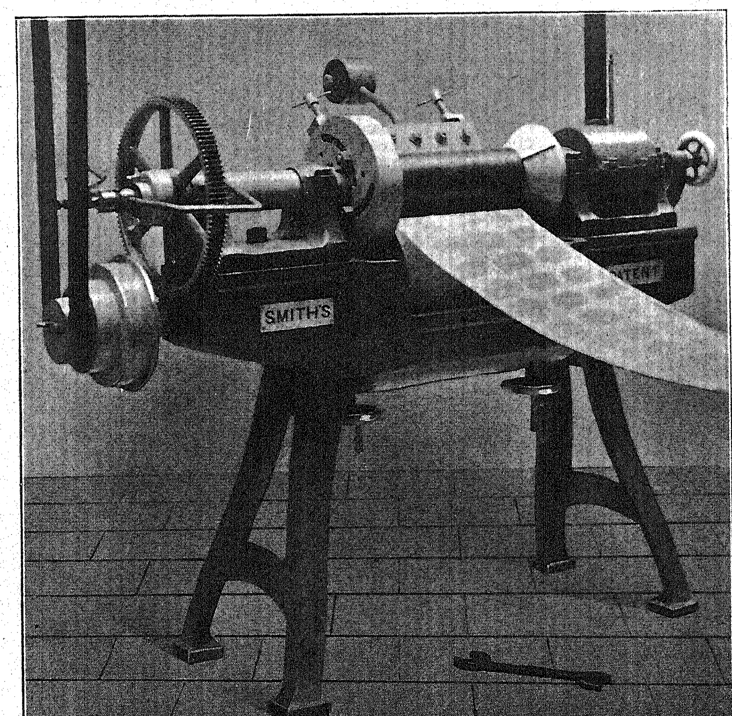


FIG. 261.—Roller printing machine. (*By Thomas Smith & Co., Hanley.*)

picture printers, submitted to Herbert Minton, of Stoke-on-Trent, trials they had made of transferring to pottery impressions taken on paper from the flat surface of metal or stone instead of from engraved lines (patent No. 12097, 14th March 1848). Minton perceived the probable artistic advantages of the system, and came to an arrangement for giving the matter a practical trial.

After many disappointments and repeated experiments, the process was at length brought into practical use as a means of mechanical decoration. It was applied to the decoration of china and earthenware, but proved most suitable for flat surfaces. Hence at an early period, we are told, glazed tiles were so ornamented; the old expensive process of ground-laying being supplanted to a certain extent. By this method, it is said, tiles used in the House of Commons under the direction of Pugin were decorated. (*Ceramic Art of Great Britain*, vol. ii. p. 203, Virtue & Co.)

Where broad, flat surfaces of colour are desired, this would appear to be a suitable process, and it is in some cases operated in a manner that gives the tile the appearance of an inlaid encaustic tile. It also enables several colours to be applied to the tile at one operation.

Messrs. Carter & Co., of Poole, refer to the process of lithography as still in operation as a means of tile decoration. (*Interesting Notes on Ornamental Tile Manufacture*, p. 14.)

Mr. H. Moorcroft kindly informs the writer that in this country lithography for U.G. decoration on tiles is not much used. Yet upon the Continent large quantities of lithos are used for tiles, but principally over the glaze; the same are subjected to a hard fire, to bring the colours up to the required brilliancy. In this style Moresque and Persian designs are reproduced.

Aerography.—The method of applying colour by aspiration or blowing on is not altogether novel; how long it has been used in the simpler form probably no one really knows. From *The Connoisseur*, vol. iii. p. 143, we learn that the brilliant ground-colouring of many beautiful pieces of "powder-blue" decorated Chinese porcelain in the great Garland collection was applied by a very ingenious device of this nature, which is said to have been invented in the Kang-hi period. "A piece of gauze was fixed to the end of a bamboo tube, and then dipped into the prepared colour, which the artist transferred to the paste by blowing through the tube. On the spaces left uncovered by this process are painted flowers, birds, and landscapes, in the richest of cobalt blues. Of this type of ware the collection contains nearly two hundred pieces, all of great value and beauty." (*Connoisseur*, vol. iii. p. 143.)

The dipt-turner's slip-bottle, which enables him to wholly or partially cover the ware, while on the lathe, with a coloured slip, is also of kindred nature.

The vapo-apparatus for applying coloured glazes, illustrated and described in another chapter, also partakes of this character.

But the aerograph or air-brush most generally used for decorative work is probably the one invented by C. L. Burdick, and sold by The Aerograph Co., of 30 Memorial Hall Buildings, London, E.C. When describing this instrument at a meeting of the Society of Arts in 1894, Mr. Burdick explained that he did not claim the original conception of the air-brush, and that the idea was first embodied in a mechanism invented by Mr. Abner Paler, of Iowa, U.S.A. What Mr. Burdick claims is that he has invented the first entirely practical and wholly satisfactory tool of its class. It is a kind of fountain-pen, the colour being contained in a receptacle near the point, and thence distributed in the form of a spray by means of compressed air passing through the instrument, and under the absolute control of the operator, so that either

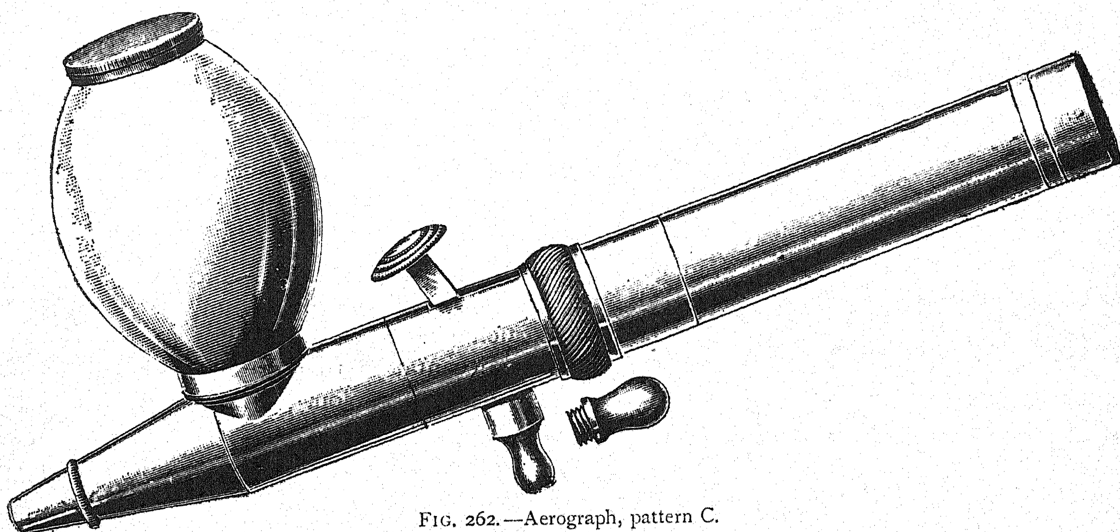


FIG. 262.—Aerograph, pattern C.

a fine line or a broad line or a broad shadow may be formed. The compressed-air supply is furnished by an air-pump, which may be actuated either by foot-pressure or any mechanical power that will develop about 8 or 10 lbs. pressure, as, for instance, a steam or gas engine. The colour may be in finely divided suspension in water or turpentine or spirits of tar or other medium, according to the work in hand, *i.e.*, in ceramics, whether to be applied to the biscuit-ware as underglaze colour or slip-decoration, or as coloured glaze or art-enamel on the biscuit, or as vitreous enamel colour on the glazed ware. Its advantages for shading and ground-laying are manifestly economical and hygienic, and have secured an extensive employment.

The pattern illustrated is the new twentieth-century model, "Pattern C," especially designed for potters' use for ground-laying, blending, tinting, etc., and is the outcome of many years' special experience of the requirements of

ceramists. To obviate the wear consequent upon the use of potters' colours, which are mostly minerals or glasses finely ground, platinum is used in the tip through which the colour comes; and parts are made interchangeable and easily replaceable.

The work of the aerograph, upon close examination, is found to be composed of colour deposited in minute particles or specks, virtually a fine stipple. For this reason, one wash or layer of colour can be superimposed upon another without disturbing the first, or working it up, a defect exceedingly frequent and annoying when the ordinary hair-pencils are used.

Mr. Milses, of Longton, recently patented a contrivance by which two or three different colours can be held in the colour-holder in separate compartments; and by this means the artists can, when *tinting* in rainbow tints, etc., quickly change the colour, and so blend the tints economically.

RECIPES FOR UNDERGLAZE COLOURS.

No. 1.—U.G. Blue-Black Colour.

6 lbs.	glaze frit No. 11.	Intimately mix and sieve twice. Place in flinted bowls and calcine in glost oven. Wash by decantation, then grind in water on a colour-pan, and dry.
6 „	chromate of iron, ground.	
3 „	black oxide of cobalt.	
2 „	barytes, ground.	
2 „	china-stone, ground.	
2 „	green oxide of chromium.	
1 „	silica, ground.	
1 „	china-clay (kaolin).	

No. 2.—U.G. Black Colour.

12 lbs.	ground chromate of iron.	Grind together in water on a colour-pan, and dry.
1 „	black oxide of cobalt.	

No. 3.—U.G. Common Brown Colour.

12 lbs.	ground chromate of iron.	Treat as No. 1.
4 „	oxide of zinc.	

No. 4.—U.G. Dark Brown Colour.

4 lbs.	ground manganese ore, common.	Treat as No. 1.
1 „	green oxide of chromium.	
4 „	ground china-stone.	

No. 5.—U.G. Chocolate-Brown Colour.

6 lbs.	zinc oxide.	Intimately mix and treat as No. 1.
4 ,,	whitening.	
2 ,,	borax.	
2 ,,	green oxide of chrome.	
2 ,,	red oxide of iron.	

No. 6.—U.G. Brown Colour.

5 lbs.	ground chromate of iron	Treat as No. 1.
3 ,,	oxide of zinc.	
½ ,,	red oxide of iron.	
½ ,,	borax.	

No. 7.—U.G. Claret-Brown Colour.

7 lbs.	oxide of zinc.	Treat as No. 1.
1¼ ,,	whitening.	
1¼ ,,	boracic acid.	
1½ ,,	green oxide of chrome.	
1½ ,,	red oxide of iron.	

No. 8.—U.G. Golden Brown.

4 lbs.	oxide of zinc.	Treat as No. 1.
3 ,,	ground white earthenware biscuit pitchers.	
1 ,,	glaze frit.	
1 ,,	boracic acid.	
1½ ,,	green oxide of chrome.	
1½ ,,	red oxide of iron.	

No. 9.—U.G. Dark Blue Colour.

4 lbs.	glaze frit No. 13.	Simply ground together in water on colour-pan, and dried.
3 ,,	black oxide of cobalt.	
½ ,,	alumina, calcined.	
½ ,,	oxide of zinc.	

No. 10.—U.G. Matt-Blue Colour.

10 lbs.	calcined alumina.	Intimately mix, calcined in china biscuit oven, or at felspar fusing heat, grind, and dry.
2 ,,	oxide of zinc.	
½ ,,	black oxide of cobalt.	
½ ,,	oxide of tin.	
⅛ ,,	soda-lime glass.	

No. 11.—Underglaze Matt-Blue Colour.

10 lbs.	calcined alumina.	Treat as No. 10.
5 „	oxide of zinc.	
½ „	oxide of cobalt.	

No. 12.—Underglaze French-Green Colour.

12 lbs.	flux (10 borax, 10 silica, 4 zinc oxide, calcined).	Treat as No. 1.
4 „	green oxide of chrome.	
1 „	oxide of cobalt.	
1 „	silica.	

No. 13.—Underglaze Bronze-Green Colour.

7 lbs.	green oxide of chromium	ground together.
3 „	flux (7 borax, 5 flint, 4 pitchers, 2 nitre, 2 whitening)	
2 „	ground pitchers	
1½ „	silica	
1½ „	glaze No. 11	
½ „	chromate of iron	
½ „	black oxide of cobalt	

No. 14.—Underglaze Victoria-Green Colour.

6 lbs.	ground calcined flint.	Treat as No. 1.
5 „	whitening.	
5½ „	bichromate of potash.	
1 „	plaster of Paris.	
2 „	fluor-spar.	

No. 15.—Underglaze Pink Colour.

30 lbs.	oxide of tin.	Calcine in china biscuit oven, wash, and grind.
20 „	whitening.	
¾ „	calcium chromate.	
¼ „	green oxide of chrome.	

No. 16.—Underglaze Dove Colour.

2 lbs.	ground felspar.	Treat as No. 1.
2 „	whitening.	
1 „	black oxide of cobalt.	
¼ „	ground calcined flint.	
¼ „	green oxide of chrome.	

No. 17.—Underglaze Yellow Colour.

For this the writer suggests:—

9½ lbs.	vitreous white tile-body.	Treat as No. 15.
½ „	yellow rutile.	

No. 18.—Underglaze Orange Colour.

4 lbs. calcined alumina.
4 „ zinc oxide.
2 „ calcium chromate.
1 „ red oxide of iron.
½ „ colourless glaze frit.
½ „ pitchers.

No. 19.—Underglaze Velvet-Green Colour.

4 lbs.	green oxide of chrome	ground together.
4 „	ground silica	
2 „	black oxide of cobalt	
2 „	ground white pitchers	
2 „	dried glaze No. 11	

No. 20.—Underglaze Peacock-Green.

12 lbs.	U.G. French green	ground together.
9 „	„ matt-blue	
3 „	oxide of tin	

No. 21.—Underglaze Neutral.

3 lbs.	ground common manganese	ground together.
1 „	black oxide of cobalt	
¼ „	green „ chrome	
¼ „	china-clay	
¼ „	silica	

No. 22.—Underglaze Japan-Blue.

3 lbs.	U.G. dark blue	ground together.
1 „	„ blue-black	
1 „	ground felspar	

No. 23.—Underglaze Willow-Blue.

15	lbs.	whitening	ground together.
10	„	oxide of cobalt	
5	„	ground flint	

No. 24.—Underglaze Pheasant Colour.

12	lbs.	flux (36 flint, 8 pearlashes)	ground together.
12	„	whitening	
4	„	colourless glaze frit	
4	„	barium carbonate	
1	„	cobalt oxide	

CHAPTER XI.

LEADLESS GLAZES AND ART-ENAMELS.

"*The use of lead in the glazes destroyed some of the most beautiful tints.*"—Prof. C. F. BINNS, *Story of the Potter*, p. 67.

CONTENTS.—Leadless glazes now in use—Precautions recommended—Opinions of experts—Defects in lead glazes—Public discussion—Essential qualities of glazes—*The Lancet* analytical commission—Government inquiry—Contemporary glazes—Individual influence of ingredients—Preparation of frits and glazes—Composition of glazes—Costs—Recipes.

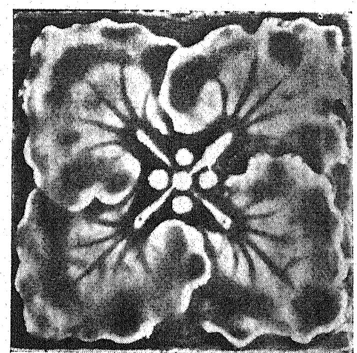


FIG. 263.—Leadless-glazed embossed tile.

HISTORICAL facts, technical records, and contemporary manufacturing practice supply abundant evidence that a considerable variety of ceramic products can be glazed in a perfectly satisfactory manner by means of leadless compositions. And the exemptions granted under the new rules relating to the use of compounds of lead in British potteries substantiate the claim that lead-free glazes are already a commercial success even in North Staffordshire, notwithstanding all that has been said to the contrary.

Moreover, certain English decorative-tile makers are supplying leadless-glazed tiles to their customers when required; and two at least of the Continental and American manufacturers claim to be able to produce good tile-glazes free from lead. It will be generally conceded that if lead-free glazes of a satisfactory nature can be made, they ought to be made; and that if decorative tiles and faience can be successfully glazed or enamelled by means of non-plumbic compositions, they ought to be

Respecting the particular series of recipes for such glazes published in the following pages, it is not claimed that they will under every possible set of conditions, favourable or adverse, yield products superior to those on the

market, or beyond criticism. What is expected of them, as the result of many experiments, is that they will yield, to the exercise of equal skill and favour, results equal to the average of contemporary products in lead glazes for like purposes, except in the case of red and French-pink glazes.

And that, proper attention being paid to the composition of the tile-bodies and to the quality of ingredients, and proper care exercised in the preparation and application of the glazes, equal, if not superior, results from a hygienic point of view will be attained at less cost.

But zeal in the advocacy of lead-free glazes will not induce the writer to deny that considerable caution should be exercised in launching these recipes into extensive use on a commercial scale. Rather would the writer advise all who put these glazes into use to trust nothing to chance that can be controlled by experiment and test; let every lot of glaze be tested thoroughly prior to use, and all glazed tiles and wares carefully examined before being allowed to be dispatched from the warehouse.

As with plumbic, so with non-plumbic glazes, the peculiarities of each works must also be provided for; different clays, different body formulæ, different kilns, different grades of product ever demand judicious adaptations of the glazes.

Again, chemistry, physics, and mechanics, though much in evidence on a modern decorative-tile factory, do not exhaust all the factors of the problem. A large volume of human nature is there also with its conflicting interests, tritely summed up by one who knows in the expression, "Everybody is here to do the best for himself."

Notwithstanding the complexity of the problem, however, no confusion of terms, and no subterfuges whatever, have been resorted to in these recipes, to enable the author to wriggle out of the fundamental principles involved in an absolute abandonment of the use of lead compounds, and, as far as practicable within the writer's knowledge, every other poisonous ingredient.

The researches leading up to these recipes have been pursued by empirical practical methods. All trials have been subjected to test in the actual manufactory kilns, not in laboratory furnaces, nor in any makeshift gas kilns; in this manner suitable formulæ were easily and surely recognized and failures immediately detected.

The most promising results were then selected and further improved, until trials were more and more satisfactory; and ultimately the best formulæ were chosen for publication. When these recipes are in the hands of experienced ceramists, who have their own formulæ and long practical experience to help them, probably further improvement will be realized; but great care should be exercised in attempting alterations, because many changes have already been tried and discarded.

Opinions of Experts.—In support of the contention that easily fusible glazes and enamels are within the range of practicability in the absence of lead, some rescripts from the writings and lectures of eminent ceramists are subjoined.

Mr. William Burton, F.C.S., in the course of a lecture delivered at Hanley on 21st February 1891, said:—"At a very early time, certainly as early as the Christian era, the Persians had learned the secret of manufacturing a true glaze, and their glaze was of a very simple composition, consisting of a mixture of clean white sand and either soda or wood ashes or potass. Glazes of this nature were very brilliant in appearance, very good for developing colours, and, in the case of the Persians, they adhered perfectly well to the ware. One of the striking peculiarities of all alkaline glazes was their extraordinary brilliance. The introduction of lead made the glaze richer and softer and 'fatter,' but it also brought with it a diminution of its brilliance, and was apt to impart to the ware a faint yellowish tinge." (*Staff. Sentinel*, 23rd February 1891.)

Again, when lecturing before the Society of Arts on 25th February 1896, Mr. William Burton observed that "Pottery with plenty of free silica in the body, or with a siliceous slip-coating, and glazed with an alkaline glaze, is the best medium for underglaze colour-work that has ever been invented; and whether in the hands of the Oriental potters, of Deck in France, or of De Morgan in England, quite manifests its superiority over the other bodies and glazes in more general use. One main reason for this superiority lies in the perfect translucence and limpidity of the glaze; while, perhaps, a still more powerful reason is that certain underglaze colours, intrinsically of great beauty, such as the turquoise from copper, the violet from manganese, and the Rhodian red which has been already mentioned, cannot be obtained to perfection under any other glaze than an alkaline one." (*Jour. Soc. Arts*, 28th February 1896, p. 324.)

Yet another excerpt from the same authoritative source. In a lecture at Hanley early in March 1891, Mr. William Burton is reported to have said:—"He considered the salt glaze was the finest type of glaze known, and he was sorry it was not more generally employed. It was thoroughly transparent and brilliant; nothing could excel the brilliancy of the silica-alkaline glazes. It was excessively thin—so thin that good salt glaze never hides any modelling which it covered, but developed it to perfection; it had not the fault of other glazes in being liable to chip or fall off; it was not, unless excessively thick, liable to craze; and was not attackable by any acid found in cookery, or any acid at all. In these days the employment of lead in glaze on cooking utensils was becoming a very serious matter—not in this country, where lead was not very much employed, but in Germany, where the Government had passed a law that no glaze should be allowed to be used from which boiling acetic acid should be able to dissolve the slightest amount of lead. He could not too

strongly insist upon the absolute danger of ever having lead in the glaze of cooking utensils." (*Staffordshire Sentinel*, 9th March 1891.)

M. Arnoux, formerly art director and superintendent of Messrs. Minton's works, commenting upon absence of crazing in certain Persian glazes, has written:—"I have no room to explain how it is that, being an earthenware, it is so much richer in colour than the modern ware made on this side Europe. I can only mention that the body of the Persian ware may be converted into a transparent porcelain by firing it hard, which shows that the sandy clays from which these are made are sufficiently saline to become vitreous. To this they owe the property of receiving, without crazing, glazes of the softest kind, and consequently of exhibiting those colours which can only stand at a low temperature, such as the Persian red, the turquoise, and that purple or violet which makes so valuable the specimens on which it is laid." (*Brit. Manufg. Industries*, p. 52, Stanford.)

Mr. John C. L. Sparkes, of the Royal College of Art, South Kensington, formerly director of the Lambeth School of Art, speaking at the Society of Arts on 7th February 1893, mentioned a remarkable circumstance demonstrating the perfect continuity of Persian glaze. To quote his own words:—"He remembered an experiment which was perfectly well carried out in Paris some years ago. A beautiful Persian vase had become chipped, and the soft interior stained a good deal, probably by bad usage. The French experts attached to the Louvre conceived the idea of washing out the body between the two skins of glaze, and they succeeded in doing so. They actually dissolved away the discoloured interior between the outer glaze and the inner . . . . and this discoloration was replaced by an appropriate body, and this very beautiful vase was restored to its original state. This showed what an important factor the glaze was. In this case it was the main thing—the body was nothing but a support. Of course that would only be possible in a pot which had a soft body, and outside it a perfectly continuous glaze." (*Jour. Soc. Arts*, 17.2.93, p. 306.)

It may be said that modern Persian glazes contain lead, for Seger found lead in an opaque Persian glaze, and Persian glaze formulæ contain lead (see Chapter III.); but the writer infers that Seger did not examine transparent Persian glazes, and it has already been shown, on the authority of Mr. Burton, that Persian glazes of the best period did not contain lead.

Mr. Wilton P. Rix, in a lecture before the Society of Arts on 1st March 1899, remarked that "The use of glazes free from lead is no new practice in ceramics. The hard porcelain of the Orientals, so long the unattained ideal of the Western potter, dates far back into the early centuries . . . . while the Rhodian and Persian wares afford the altogether different type of soft alkaline glazes, yet still free from lead. . . . . The importance of the elimination of lead from all glazes needs no demonstration. The attention

lately called to its deleterious effects, and the statistics which have been published respecting them, make it necessary for the welfare of the industry that every means should be taken to reduce, if not finally to eradicate, the cause of such serious results. . . . . The disastrous effects of lead in certain cases cannot be too strongly stated. When developed in its most virulent form, lead poisoning is the undoubted precursor of paralysis, blindness, and death." (*Jour. Soc. Arts*, 3.3.1899, p. 333.)

Dr. Seger, of Berlin, according to Bleininger's translation, says:—" I have now been engaged for many years in trying to do away with the poisonous lead oxide as a glaze material as much as possible. . . . . I have attempted the solution of this problem in another way, and have followed the porcelain glazes, glazes high in alumina which as fluxes contain alkalies and lime, whose fusibility is increased by the partial substitution of silica by boric acid. It is thus seen that with the exception of the lead oxide there are present practically the same substances which in greater or smaller quantities make up the ordinary glazes. In my experiments, however, the main consideration was the maximum and minimum amount of the substances admissible in the glazes in order to produce good, smooth, and transparent coatings of glass on the body at the temperature of the ordinary whiteware glost burn. The lead oxide, without doubt, is the metallic oxide most suited for the production of glazes. Its insolubility in water, which permits of its use in the free condition; the instability of its compounds, especially of the carbonates and sulphates; its fusibility and the fusibility of its silicates . . . . are properties which no other metallic oxide can attain; these are all reasons why lead oxide is so suitable as a glaze material. The only fault it possesses is the poisonous character of its compounds, which endanger the consumer as well as the workman. If I now make the attempt to replace lead glazes by lime-alumina glazes, I do not assert that this can always be done. The lead glazes will still be necessary in all the branches in which the pottery requires an artistic treatment. However, the substitution will be possible in the glazing of whiteware, also of ordinary earthenware, that is, for plain-coloured or light whiteware, as well as those decorated with underglaze colours of the most various kinds.

" At this point I wish to call attention to the fact that the pottery coated with a glaze free from lead assumes a different character entirely; it loses the gloss peculiar to lead glazes, and assumes more the character of the porcelain glazes. In how far this may injure or benefit the industry commercially, I shall not venture to say; but I believe that this question will not offer an obstacle to the use of glazes free from lead. . . . . Collecting the results of this investigation, it is seen that the use of alkali-lime glazes is confined to much more narrow limits than the application of the lead glazes, and that much more care is necessary in their preparation. . . . . Yet it will be

possible to replace a large number of lead glazes by such." (*Seger's Collected Writings*, Bleininger's transl., vol. i.)

With genuine and unfeigned respect for Dr. Seger's methods and opinions, the writer, nevertheless, after careful and prolonged investigation, claims an equal right to judge by results; these appear to carry the solution of the problem a stage further than Seger did, and to enable artistic wares to be produced without the use of lead.

But Seger asserts that leadless glazes have not the gloss peculiar to lead glazes; if he refers to the greasy surface-shimmer, then that may be so, for a leadless-glaze surface is, when the glaze has been well compounded, remarkably pure. As to comparative glossiness, however, apart from shimmer, the writer's experience shows that certain leadless glazes, dipped on the same pieces of ware and burned in the same saggar with lead glazes, yield results equal to lead glazes, and sometimes distinctly more glossy.

Differences in experimental results, and consequent differences of opinion, are of course inevitable, because so very many different lead-free glazes can be made that no individual experimenter can personally try every possible permutation of the elements and conditions concerned; and the nature of the bodies upon which the glazes are applied also exercises considerable influence upon results.

It should be observed, however, that Seger does not say leadless glazes have no gloss. His remarks are:—"Pottery coated with a glaze free from lead assumes a different character entirely; it loses the gloss peculiar to lead glazes, and assumes more the character of the porcelain type." Is any discredit thereby attached to leadless glazes? Is not porcelain by far the most highly esteemed and valuable of ceramic products in every civilized country throughout the world, both in the eyes of the potter and the connoisseur? Why are superior white earthenware bodies nominally elevated into "semi-porcelains," "opaque porcelains," and the like? At anyrate Seger ventured the rider:—"I believe this question will not offer an obstacle to the use of glazes free from lead. . . . . It will be possible to replace a large number of lead glazes by such."

Anent Dr. Seger's assertion that much more care is needed in the preparation of leadless glazes, possibly his acquaintance with hard porcelain glazes and simple lead glazes caused him to look upon fritting as a tedious and comparatively irksome business; and so no doubt it is. Simple mixtures of white-lead or galena with silica and Cornish china-stone are very easy to prepare when the potter buys the lead compound ready for use; but the choicest of modern decorative-tile glazes are not so elementary as all that, even when lead is used. Many of the best are compounded of carefully prepared frits, blended into complex mixtures, quite as much a task, if not more so, than numbers of the recipes for glazes herein proposed; and fritting

is a common expedient in all the best whiteware potteries and tileworks in Great Britain.

Why, then, should complaisance or indolence cause lead-free glazes to be packed away to limbo? Let us refer to Mr. W. Burton, F.C.S., for an explanation. He has asserted that "For the most part alkaline glazes are no longer used, except for such colours as cannot be obtained by any other means; such colours, for instance, as the turquoise glaze from oxide of copper, or the violet glaze from oxide of manganese. Most modern coloured glazes are made with a large proportion of oxide of lead, because such glazes are more manageable, melt at a lower temperature, and do not alter so sharply in tint with varying fires; and with regard to the proportion of oxide of lead in the glaze, the larger the proportion, the darker and richer will the colour be, and the more bloomy and velvety its surface. Briefly, lead glazes give richer colour, alkaline glazes more brilliant colour. Most important is the action of fire; for, starting with the same mixture of glaze and colour, it is possible to produce the most curious variations, not merely in tint, but in actual colour-shade, by exposing it to different degrees of heat. All colouring bases show this to some extent, and some few coloured glazes have their colour entirely destroyed by exposure to a temperature only slightly higher than that needed to develop their full tint, because at a higher temperature the glaze not only dissolves the colouring matter, but decomposes it, forming new compounds which may be colourless, or of quite different colour to the one desired; the deep crimson glaze, known as *sang-de-bœuf*, is very liable to this decomposition from over-firing.

"Glazes coloured with oxide of cobalt, oxide of iron, and oxide of manganese undergo a very curious bleaching action if they are fired at too high a temperature, or even if they are exposed to their proper temperature for too long a time. While oxide of copper, being somewhat volatile at a fairly low heat, is the most unreliable of all colour-bases when dissolved in a glaze; and, whether dissolved in an alkaline or a lead glaze, is so altered in tint by alterations of temperature in firing that it might be possible to use it as a trial to fire by, judging the temperature by the tint obtained with a glaze containing a given proportion of oxide of copper.

"Beautiful and precious as these coloured glazes are, they are so difficult to keep constant in tint, from the readiness with which they show even slight differences in composition or in firing, that the pottery manufacturer who feels himself tied down to produce mechanical effects finds them the most troublesome of all colours to manage." (*Jour. Soc. Arts*, 28th February 1896, p. 332.)

In the foregoing it is declared that glazes containing a large proportion of oxide of lead melt at a lower temperature, and do not alter so sharply in tint with varying fires as alkaline glazes. With regard to the melting, a customary

finishing temperature for majolica glaze kilns, the writer understands, is Seger Cone 07, equivalent to 1010° C.; or occasionally Cone 08, equal to 990° C. Mr. Watkin gives the range of his recorders suitable for (soft) glaze kilns for tiles, etc., as from 9 to 17; that is, from 830° C. to 1030° C. Now, it has been experimentally ascertained by Mr. W. Jackson, A.R.C.S., instructor in pottery and porcelain, S.C.C., that several of the leadless-glaze frits, of which recipes are given in this volume, attain complete fusion at temperatures between 700° C. and 825° C., and the most important leadless glaze of this series attains complete fusion at 900° C.

With regard to alteration in tint under varying fires, we have it on the authority of Professor Binns that "the use of lead in the glazes destroyed some of the most beautiful tints"; and Mr. Burton himself confesses that modern coloured lead glazes give great trouble in this respect, so much so that the makers "find them the most troublesome of all colours to manage." This almost relieves us from the obligation of discussing the point, but it may be well to point out that Mr. Ernest Mayer has shown that pink colour associated with a certain leadless glaze may be heated up to a temperature of Cone 9 and melted in the glaze without destruction of the tint; yet with ordinary lead glazes at much lower temperatures the tint had been injured materially. (*Trans. Am. Cer. Soc.*, vol. i.; and *Pottery Gazette*, December 1900, p. 1369.)

Turquoise and violet are admitted to be more easily obtained by means of alkaline glazes; so that with this item, as with the melting-point, the reasons assigned for neglecting lead-free glazes do not bear discussion very successfully.

Defects of Lead Glazes.—That lead glazes are not as technically blameless in other respects than their poisonous qualities, as Dr. Seger and others have assumed, may be demonstrated by reference to the matured opinions expressed by eminent practical ceramists of large experience.

Sir Henry Doulton's opinion may be inferred from a remark he made at a meeting of the Society of Arts on 7th February 1893, when, among other things, he said:—"There was a popular misconception with regard to glazing which he should like to dispel. A bright glaze, as a rule, gave no security for durability. . . . . To take a simple illustration, a common Sunderland milk-bowl with a beautiful cream-coloured glaze inside was very nice to look at, but the body on which the glaze was run was comparatively porous; and it would be seen, if any housekeeper attempted even to salt anything in that pan, that the glaze would come off; it would not require even acid to take it off." (*Jour. Soc. Arts*, vol. xli. p. 304.)

Karl Langenbeck, a most accomplished American ceramist, freely admits the crazing tendencies of lead glazes. In a paper read at Cincinnati he is reported to have said:—"I am frequently asked why it is not possible to make

glazed tile that will not craze. It is possible. But if you expect to produce effects such as you obtain with the present glazes, if you demand the soft lead glazes that are highly refracting, and insist upon having the brilliancy heightened by having the glaze put on the pieces in a thick layer, the freedom from crazing can only be obtained in a small percentage of ware. . . . . But it is claimed a white wall-tile is surely thin-glazed, and should be as free from crazing as table and kitchen ware shows itself to be under more exacting use. But the bulk of our wall-tile practically all craze. Our domestic wall-tiles are all made with highly-refracting lead glazes. . . . . When builders waive their demand for brilliant, straight, and uniformly tinted wall-tile, and have them hard fired and covered with alkali-lime glaze, they will get tile that will not craze." (*British Clayworker*, July 1899, p. 106.)

Again, he has written:—" In so-called majolica . . . . the coloured glazes are put on thin, and the ware is generally very imperfect technically, the glazes being minutely crazed and the body very porous and brittle." (*Chemistry of Pottery*, p. 127.)

Mr. William Burton, F.C.S., in the article on Pottery and Porcelain in Dr. Thorpe's *Dictionary of Applied Chemistry*, writes or quotes thus:—" A good glaze should answer to the following properties: (i.) It should be clear, brilliant, and thin, so as not to hide modelled work. (ii.) It should have a suitability to and agreement with the body, both in composition and dilatability, as neither to chip off from the sharp edges of the body, nor to break up into minute cracks (crazes) upon its surface. (iii.) It must be hard enough to resist wear, especially if used for culinary purposes. (iv.) It should not be attacked by water, or by acid vapours; and, if used for culinary, domestic, or sanitary purposes, should not be attackable by any acid save hydrofluoric.

" There are but two glazes in ordinary use which can be said to answer these conditions perfectly, and they are the salt glaze so extensively applied to stoneware, and the glaze of hard porcelain; though the glaze on the best English soft porcelain ranks but slightly below them. . . . . Most of the other glazes in common use are defective in one or more of these points; though such faultiness may not prevent them from serving most of the purposes for which a glaze is intended. The commonest and, at the same time, the most vital of these faults is what is known as 'crazing.' . . . . These cracks, fine as they are, readily absorb fluids; and when they occur on pieces used for the purposes of the toilet or the table, become not only offensive, but are said to be positive sources of danger from the fatty or oily fluids they have absorbed, forming possible breeding grounds for bacteria." (*Dictionary of Applied Chemistry*.)

Mr. H. Watkin, in his notes on heat recorders, mentions an earthenware body which was found by experience to be quite satisfactory when fired to a

temperature equivalent to 1110° C., but if fired only to 1090° C. it invariably crazes when glazed (presumably, of course, with ordinary lead glazes).

Further, it is well known in the industry that when pure, clear, water-like transparency is required in a glaze, lead compounds must be reduced to very low proportions in the glaze composition. A glaze containing 25 per cent. or more of lead oxide is almost certain to yield greenish or brownish tints when the glaze is applied to whitewares.

Public Discussion.—A review of the public correspondence and discussion about these matters would fill volumes without perhaps advancing the subject much. One incident, however, may be mentioned *in extenso* here, namely, the exchange of views between Her Grace the Duchess of Sutherland and the Longton and Fenton China Manufacturers' Association.

In one of the published letters Her Grace wrote as follows:—"I now come to the point which underlies your whole letter—the question of the possibility or impossibility of applying leadless glazes to English pottery manufacture, and particularly for china, for which alone you speak. You assure me that leadless glazes are impossible, and that if they were used it would inevitably drive the trade out of the country. No one wishes to see that done; certainly I do not. I cannot help attaching considerable importance to your declaration, speaking as you do for the China Manufacturers' Association. The matter, therefore, resolves itself into this—that if leadless glazes are not possible, it is a weakness on our part, we who have been led to believe from the statements of Dr. Thorpe and other experts that they are 'within the reach of manufacturers,' to still pin our faith to an impossible thing; but, on the other hand, if they are possible, the weakness on your part in declaring them otherwise is many times greater, because you have an infinitely greater opportunity than we outsiders can possibly have in testing them and in judging them, not with semi-ignorant experiments and in a half-hearted spirit, which naturally leads to failure, but with the full knowledge that science offers you combined with the highest motives of humanity that you assure me you possess. Your responsibility, therefore, in spurning and denouncing them will be greater than ours in adhering to our hope in them. I therefore ask you to be kind enough to tell me categorically what are the essentials of a glaze, and in what respect leadless glazes fall short of those essentials?" (*Staff. Sentinel*, 19th July 1900.)

To this portion of Her Grace's letter the Longton and Fenton China Manufacturers' Association replied as follows:—"As to the possibility of the introduction of leadless glazes on the wares made in this country . . . . Dr. Thorpe is undoubtedly an expert chemist, but he cannot be described as an expert in pottery manufacture, and who the other experts are we have no idea; for every expert potter in this country is of one opinion, viz., that under our present manufacturing conditions leadless glazes are not within the

reach of the manufacturer for the bulk of his productions. The idea seems to be that leadless glazes in English pottery are some new compounds just discovered, which the English manufacturers are too stupid or too obstinate to use. On the contrary, many English manufacturers have been experimenting with leadless glazes, and even using them on a large scale, for a longer or shorter period, during the greater part of this century. It is quite possible to produce a dinner-service like that possessed by your Grace, or even a dozen such services, especially if price is not a consideration; and a similar service would have been made for you by many manufacturers at any time during the last twenty-five years. The trouble to the manufacturer would come in if he were compelled to use leadless glazes on the whole or even on a considerable portion of his productions. So far as mere cost of glaze is concerned, leadless glazes are probably at least 20 to 25 per cent. cheaper than lead glazes, which in itself would be a sufficient reason to induce all manufacturers to use them were other qualities equal. The cost of the glaze is, however, a matter of little moment, if the working properties are so uncertain that one cannot produce the largest possible proportion of best goods. It is the uncertainty of leadless glazes in actual working on the large scale that has prevented, and still prevents, any such general use of leadless glazes as Dr. Thorpe declares to be possible.

"The qualities by which we judge the working value of a glaze may be summed up as follows:—

"(1) It must possess the same coefficient of expansion as the ware to which it is applied, in order to avoid 'crazing' or 'peeling.'

"(2) It must run freely enough to cover the ware perfectly with all its modelling, but it must not flow so freely as to run off straight-side pieces.

"(3) It must be clear and brilliant at such a temperature as will not deform the piece of ware, and must remain clear and brilliant at the lowest temperature found in a pottery oven.

"(4) It must possess a sufficiently high refractive index as to be capable of giving the utmost brilliance to the colours used with it.

"(5) When exposed in thin layers to the slow firing and long-continued cooling obtained in certain parts of pottery ovens, it must show no signs of devitrification.

"(6) It must be of such a nature as to dissolve certain metallic oxides without unsightly separations and blotches.

"(7) It must dip easily, and must not be readily detached from the pieces, before firing, during the handling necessary in cleaning and placing.

"These conditions are sufficiently well fulfilled by the lead glazes in ordinary use in the trade; whereas the best leadless glazes yet known—and this, remember, after endless experiment—fulfil these conditions only partially and imperfectly. They need greater care at every stage of the process, and they

can only be produced at all satisfactorily in the specially favoured portions of an oven. We have, however, to fill the whole of our ovens, and, therefore, it is absurd to say that leadless glazes are now within reach of the manufacturers." (*Staff. Sentinel*, 28th July 1900.)

Now, considering that the chairman of the Longton and Fenton China Manufacturers' Association at that time was the local agent of one of the largest producers of potters' white-lead, and that the secretary at that time was admittedly inexperienced (see *Pottery Gazette*, February 1902, p. 185), the Association may be forgiven for appearing to entertain superstitious fears about all things leadless.

Their specification of the essential qualities of a glaze, although little more than a copy of those enunciated by Langenbeck on p. 48 of his *Chemistry of Pottery*, for totally different ceramic products, savours of the wish being father to the thought; for, as a matter of fact, no single formula for lead glaze seems likely to comply with the entire specification. And Mr. William Burton confesses in Dr. Thorpe's *Dictionary of Chemistry* that but two glazes perfectly conform to his ideas of a good glaze; and, strange to say, neither of the two he names contains any lead compounds whatever. But the crux of the whole matter, viz., a categorical statement of "In what respects leadless glazes fall short of those essentials," is feebly met by the China Manufacturers' Association in indefinite generalities, compressed in their few closing sentences, as above.

This is greatly to be regretted, for definite and reliable information upon this side of the subject is precisely what all concerned most ardently desire. In respect of this omission, however, a letter was addressed to the *Pottery Gazette* shortly afterwards under the heading, "In what respects leadless glazes fall short," and, taking the items seriatim, carefully traversed the whole ground. The following abridgment will indicate the tenour of the letter:—

"Essential No. 1.—'It must possess,' etc. Here we have what one of the most influential trade combinations affirms to be superlatively the indispensable essential of a glaze. How remarkable! considering the fundamental importance attached to this condition by the Association, they omitted to name the particular coefficient of expansion required. No attempt is made to show what the coefficients actually are, nor in what degree leadless glazes do not conform to them. This is a glaring defect in their reply, but we will try to make up for it by referring to the conclusion of Langenbeck, viz.: 'It is true, however, that the alkali-alkaline earth glasses allow a greater range of composition of the body between the manifestations of crazing and shivering than do lead glasses.' Leaving our readers to form their own conclusions from the foregoing, we turn now from the theoretical to the practical. What do practical potters say? Some of them assert that leadless glaze crazes; others express their opinion thus: 'You can't craze it; I've tried it in the strongest

acids and ointments I could get.'—'This plate has been purposely cooked upon every morning for twelve months, and is sound now.'—'I have no hesitation in saying that the tendency to craze is very much less than with lead glaze.'—'It seems to be freer from liability to craze than our lead glaze.'—'It is sound as to crazing.'—'It has not crazed at all.'—'As for crazing, we have never seen a piece.'—All this from men of long and large experience, who have in every instance known the formula, and applied and tested the glazes on their own works. Many abstruse problems in expansion will occur to the experienced potter, as, for instance, the varying effects in thick and thin dipping causing crazing and soundness to appear on the same piece of ware; the effects in cast and pressed wares of similar chemical composition; the effects in plastic-pressed as compared with dust-pressed articles. . . . . Clearly, chemical composition is not the sole arbiter in these matters. . . . .

"Essential No. 2 reads: 'It must run freely enough,' etc. Lead glazes do not all conform to this condition. Some run down so much that droppings have to be ground off before the articles will stand upright; hence it is not absolutely essential that leadless glazes should accomplish what is not now accomplished by lead glazes. Each must be invented and corrected to suit the class of wares and the degree of heat required of them. The vast bulk of leadless glazed ware now being produced at several potteries is evidence that certain leadless glazes do conform to the specified requirements.

"Essential No. 3.—'It must be clear and brilliant,' etc. Whether leadless glazes fall short of this essential must finally be judged by results; and as many experts and distinguished practical potters fail to differentiate the one from the other by simple inspection, when shown several half-and-half dipped specimens, it must certainly be equally impossible for outsiders to do so; and therefore, in many duly attested instances, it has been clearly established that leadless glazes are not less brilliant than lead glazes that are now in actual use for like purposes.

"Essential No. 4.—'It must possess,' etc. Many complex influences are at work modifying and more or less neutralising the phenomena produced to our senses. Sir Henry Roscoe has stated in relation to glass that 'The higher the atomic weight of the metal it contains, the greater is the specific gravity of the glass and the higher is the refractive index.' Thus it seems that the possibilities of refraction are in the favour of glazes containing lead compounds; but as this is greatly modified by the percentage of lead oxide present, and as, on account of the softness, easy abrasion, lessened intensity of whiteness, and less range between crazing and shivering points when applied to articles of pottery, it is not found desirable to use an excessive proportion of lead, the advantages on the side of lead are much reduced.

"Essential No. 5.—'When exposed,' etc. The Longton and Fenton China Manufacturers' Association should have described some of the signs of devitri-

fication, and have proved to what greater extent these were usually found upon leadless-glazed ware as against lead-glazed ware. This they omitted to do. To assert that the best leadless glaze yet known fulfils this condition only partially and imperfectly is too indefinite, and such bare assertions cannot be valued at a higher rate from associations than they would be from individuals.

"But is lead the only preventative for devitrification? .... Upon reference to Langenbeck we are introduced to another: 'The potter has found empirically that no glaze can be perfect without the addition in certain proportions of either clay, felspar, or Cornwall stone, and the chemist will readily recognise that the new element introduced by these materials is merely alumina, and that it is this and other chemically similar elements which keep the glaze from devitrification.'

"Essential No. 6.—'It must be of such a nature as to dissolve certain metallic oxides,' etc. The Association does not tell us what oxides are referred to, nor which of them leadless glazes have failed to dissolve. We know, however, that lead glazes do not dissolve oxide of tin, chromium oxide, chrome-iron ore, etc.; therefore it cannot be reasonably claimed that leadless glazes must dissolve them. The case of underglaze colours is also *in contra* to the dictum of the Association." (*Pottery Gazette*, September 1900, p. 1016, Scott, Greenwood, & Co.)

With regard to devitrification, referred to under Essential No. 6 in the foregoing, Professor Orton, of Ohio State University, has written:—"It is only by the use of alumina that we can prevent devitrification during the long cooling in the kiln." (*Trans. Am. Cer. Soc.*, vol. v. p. 50.)

And again:—"A well-known principle is beautifully illustrated in the consequence, *i.e.*, the power of alumina to prevent devitrification." (*Ibid.*, p. 315.)

"The Lancet" Analytical Commission.—The public interest taken in the subject was so great as to arouse to practical action even the proprietors of *The Lancet*, who, in the autumn of 1898, appointed a special analytical commission to thoroughly examine specimens of leadless glazes, and pottery ware glazed with leadless glazes. After completing their work they reported as follows:—

"Lead poisoning in the Potteries proceeds apace, and must do so until, as we have remarked before in these columns, the Home Office takes one of two courses—either prohibits the use of raw lead, or by suitable regulations makes the introduction of harmless glazes a paying or practicable affair for the manufacturer. How urgently prompt and effective legislative action is needed is evident when we consider that, under the new Act of 1895, the returns for the year 1896 showed three hundred and eighty-seven cases of lead poisoning from the Potteries, and further statistics show a decided increase upon this number. English pottery work and English pottery products stand first in the world. It is a terrible stigma, however, upon this position that in some

branches at least this excellence is attained at the expense of so much human suffering.

"The seat of the mischief, as everyone knows, is lead, and the question to be decided is whether raw lead can be made harmless, or dispensed with altogether. To make raw lead harmless it has been suggested to fuse it first with borax, silica, etc.—a process technically termed 'fritting'; but clearly this preliminary precaution involves the handling of raw lead in the preparatory stage. The risk, however, of lead poisoning would be thus considerably lessened where it now most occurs—that is, in the cases of those whose business it is to grind the 'frit' into powder and to dip the ware in the glaze subsequently prepared. The lead in a 'frit' is much less soluble in the gastric juice than is raw lead, and the evil effects of absorption of lead during both the grinding and dipping processes would be largely avoided by the adoption of 'fritted' lead. . . . .

"We next turn to the possibility of doing away with lead altogether. Obviously, could this be done without interfering with the peculiar and delicate requirements of the art of glazing, we might confidently hope for a speedy and satisfactory solution of a very difficult question. An enormous number of laborious experiments have been made on this promising side of the subject, with the result, we may hope, that the introduction and adoption of practicable leadless glazes will become before long an accomplished fact. But obviously nothing short of the evidence of experience can be expected to satisfy the industry on all points. As a small, though, we think, encouraging and instructive contribution to the question, we now offer the results of some experiments which we ourselves have made with certain leadless glazes in *The Lancet* laboratory during the last month. We cannot, of course, lay claim to the possession of practical knowledge or judgment in this matter. Our interest in the question is necessarily a limited one, but it is a vital interest, the points at issue affecting the well-being of those engaged in a beautiful but at present dangerous art.

"Our attention was recently drawn to the important results of a great number of arduous experiments directed to the practicability of producing leadless glazes, which were undertaken by one who has spent much of his time in the Potteries, and who has an extensive practical acquaintance with the industry.

"These results have been published by the author, Mr. William J. Furnival, the failures as well as successes being wisely recorded. Some of the successes are illustrated in specimens placed on view, by permission of the Science and Art Department, in the Geological Museum in Jermyn Street. By the courtesy of Mr. Furnival, we have obtained some specimens of the glaze and of the wares finished by its means. They consisted of various types, such as saucers, cheese-plates, dessert-plates, plaques, etc., all of which we have examined and

tested and submitted to experiment. No. 1 was a leadless glaze, marked No. 2855, and described as having been used in the dipping of all the samples of ware marked 2855. Examined for lead, this glaze gave absolutely negative results. Borax was an important constituent. When tried on 'biscuit' in the oxyhydrogen flame, a clear uniform glaze resulted. The second specimen was a saucer, one half of which was glazed with lead glaze, and the other half with leadless glaze. This appeared to us to be a perfectly successful demonstration of the practicability of using leadless glaze. In appearance the leadless glaze was in every way as good as the lead glaze. Careful chemical test showed the presence of lead in one case and the absence of lead in the other.

"The specimen taken as a third example was a dessert-plate with coloured pattern and gold border. *The glaze was excellent and was free from lead.*

"These examples will suffice, but we may add that we have examined and tested in all fourteen pieces with satisfactory results.

"The lead was tested for in two ways. First, on a portion of the plate a mixture of carbonate of soda and potash was fused before the flame of a powerful blow-pipe. The melted mass, after cooling, was washed off in hot dilute hydrochloric acid, and sulphuretted hydrogen was passed through the solution. There was never any indication of lead in the glazes marked 'leadless.' As a check on this test the plate was afterwards sprinkled with powdered fluor-spar, and moistened with strong sulphuric acid and gently warmed. The glaze was thus attacked by the hydrofluoric acid generated, and the lead, if present, would be liberated from the flux. The plate was next flooded with water, and sulphuretted hydrogen was passed through the liquid. This test answered very well with ordinary lead-glazed ware, but in no case gave any positive response with the leadless-glazed ware so described and placed at our disposal by Mr. Furnival.

"We consider that these results are of the utmost importance, for they indicate the probability of satisfactorily substituting absolutely leadless glaze for the old veneer without detriment to the beauty and finished appearance of the product. It seems to us, therefore, that the ground should be perfectly clear for action by the Home Office. Either leadless glazes are practicable or they are impracticable. It is for a committee of experts to decide one way or the other with the evidence of practicable trial before them. There is no proprietary right whatever connected with the use of these glazes. Their formulæ are published and fair practical trial and criticism are invited. We understand that already some large pottery manufacturers and others with a considerable experience of the industry have tried these leadless glazes on a practical scale with excellent results.

"It may be hoped, then, that the day is not far distant when the Government will be in a position to demand the abolition of raw lead in glazing, and to compel the adoption of safe frits, or, better still, leadless glazes,

without inflicting any hardship on the potter, or causing any hindrance to the pursuit of his art. The alternative is to bring lead poisoning under the Workmen's Compensation Act.—*The Lancet* Laboratory." (*The Lancet*, 7th January 1899.)

Inquiry by Home Office Experts.—On 7th May 1898 the British Government appointed Professor T. E. Thorpe, LL.D., F.R.S., in conjunction with Professor Thomas Oliver, M.D., F.R.C.P., to institute a special inquiry into the hygienic question involved in the use of lead in pottery processes; and on the 21st February 1899 these gentlemen presented their report.

After visiting many potteries in Great Britain, Belgium, Holland, Denmark, Sweden, and Germany; personally witnessing all processes in which lead compounds are used in the manufacture of pottery; and interrogating many of the leading employers and a large number of the workers in different departments, in addition to making a chemical examination of a variety of samples of ware, frits, glazes, and pigments, they arrived at the conclusion that "We have no doubt whatever that leadless glazes, of sufficient brilliancy, covering power, and durability, and adapted to all kinds of table, domestic, and sanitary ware, are now within the reach of the manufacturer. And we have reason to believe that this fact is now more generally admitted by the trade itself than it was six months ago. . . . . Leadless glazes are equally applicable to white, cream, buff, and printed tiles. We have seen excellent examples of tiles so glazed." (*Report on the Employment of Compds. of Lead.*)

Terminology.—It will probably have been observed that no rigorous distinction between glazes and enamels has been attempted in this work. The two terms have become so inextricably confused in the ordinary parlance of the industry, that no literary effort is ever likely to permanently unravel the tangled skein.

Even the term *majolica*, although only a secondary classification, is not used by everyone in the same sense. Much of the ware known as majolica should, on the authority of both Arnoux and Burton, be designated "Palissy." Binns, referring to Palissy, observes:—"The coloured glazes which he employed were beautifully rich and pure. His work is devoid of the opacity which distinguishes and, as some think, disfigures that of Luca della Robbia; but instead there is a pellucid transparency as of pebbles seen through water. All his productions are, however, not of this class." (*Story of the Potter*, p. 80, Newnes.)

Arnoux writes:—"I have given the name of majolica to that class of ornament whose surface is covered with opaque enamels of a great variety of colours." (*Brit. Mfg. Industries*, pp. 50–51.)

Burton, at the Society of Arts, said:—"By transparent coloured glazes we mean those in which the colouring matter is perfectly dissolved by the molten glaze . . . . opaque coloured glazes, which are opaque because the colouring

matter is not dissolved. . . . . Both the transparent and opaque varieties of coloured glaze are spoken of by potters as enamels, but this term ought in strict accuracy to be applied only to the opaque varieties." (*Jour. Soc. Arts*, 28th February 1896, p. 331.)

Langenbeck writes:—"The word *enamel* has attained a special significance which the public frequently misapplies, using it indiscriminately for all glazes or glassy coverings. Technically, the word enamel means a non-transparent glass, completely covering the body upon which it is melted." (*Chemistry of Pottery*, p. 46.) Again, Langenbeck writes:—"Ceramists are inclined now to use the term 'faience' in distinction from the application of the word 'majolica,' using it to designate potteries with transparent glazes, and majolica as a generic term for potteries with intransparent glazes." (*Chemistry of Pottery*, p. 45.)

Leon Lefevre defines enamels as "coloured vitreous substances. These are divided into transparent enamels, which are plumbiferous or alkaline, and opaque enamels, which are generally stanniferous, and are used especially in the manufacture of faiences." (*Architectural Pottery*, p. 385.)

Hermann, as translated by Charles Salter, says:—"It is difficult to define strictly the difference between enamel and glass. Under the former term is, however, understood a fusible opaque or transparent glass flux (often coloured by means of metallic oxides)." (*Painting on Glass and Porcelain*, p. 17.)

Muspratt states that enamels are substances of the nature of glass, differing from it, however, by a greater degree of fusibility or opacity. They are coloured by different metallic oxides, to which certain persistent fusible salts are added, such as borates, fluorides, phosphates, etc. . . . . Enamels are distinguished into transparent and opaque." (Muspratt's *Chemistry*, p. 817.)

With all this diversity of opinion among authorities as to the meaning of the terms *Enamel*, and *Glaze*, and *Glass*, the work of reconciling and fixing upon specific definitions appears insuperable.

Excessive Perfection.—It has been most authoritatively asserted that a colour or a glass may be too pure or over-refined to secure the most artistic effect.

Professor Delamotte wrote:—"Blue is produced by the addition of oxide of cobalt in various quantities and various degrees of purity. The impure oxide, just as it is procured from the mines in Germany, appears to produce the pleasantest tint. . . . . Probably if the native oxide of cobalt, with all the impurities which naturally cling to it, were more frequently used instead of the imitations of the natural impurities made by the addition of other materials to the refined oxide, the old colour could be reproduced more exactly." (*Cassell's Technical Educator*, vol. ii. p. 219.)

W. Burton, F.C.S., has said:—"It has proved impossible hitherto, by most cunning device of combination or mixture, to obtain from purified oxide of cobalt and oxide of copper some of the tones that the Orientals got by working with impure or earthy mixtures, in which the cobalt or the copper were mingled with other substances in indefinite proportions, and in this respect the advances of modern chemistry have caused a distinct loss to the potter." (*Jour. Soc. Arts*, 28th February 1896, p. 333.)

Respecting glass, Professor Church has written:—"A glass which is absolutely perfect as a glass may be rightly devoted to the construction of optical instruments, but is incapable of completely realising the poetry of colour." (*Cassell's Technical Educator*, vol. ii. p. 235.)

Will it then be straining analogy too far to suppose that a glaze or art-enamel need not necessarily be absolutely perfect to secure artistic effect, or, indeed, to enable it to serve its most manifestly useful purpose in the province of hygiene?

The greasy shimmer associated with glazes containing large percentages of lead oxide is certainly more or less displeasing to an eye accustomed to the purer surface of lead-free glazes; the eye delights to see clearly into a glaze, and this is not always possible with lead glazes when heavily charged with lead compounds, because of the shimmer or black-leaded appearance of the surface.

For want of a more suitable way of escape, this feeling has voiced itself in the demand for roughened, eggshell, dull, "matt" surfaced glazes.

So pressing has this demand become, that there is scarcely a single manufacturer of eminence who does not cater for this fashion.

Dull-Surface or Matt Glazes.—Glossiness of surface, perfect transparency, and silk-like smoothness to touch, though particularly pleasing when observed upon small pieces of ware occupying only a limited space in the field of vision, as in table-wares, toilet-wares, plaques, vases, and the like, upon which the effect is kindred to that of polished gems, are not always equally desirable and delightful when exhibited upon large surfaces, such as interior walls or exterior façades.

In such circumstances excessive glossiness may even become unendurable, or at least too distracting to be tolerated with comfort. For this reason distemper paints are often preferred to varnish paints for extensive wall surfaces.

With decorative faience, chaste embossments and subdued tones of colour modify these effects, but do not of themselves entirely remove the objection. Hence for special cases all leading manufacturers find it advisable to produce at least some of their wares with comparatively non-reflective surfaces—"dull finish," "eggshell glaze," "matt glaze," "antique," etc.

Professor Binns tells us that forty years ago Mr. R. W. Binns, his late

honoured father, director of the Royal Porcelain Works, Worcester, conceived the idea of covering the brilliant surface of a porcelain glaze with a semi-lustrous or texture colour, with the object of checking the strong reflections of a shining glaze; and although certain buyers refused to acknowledge the merit of it, the originator set the work aside, saying that some day it would be sought after. Fifteen years later the prophecy was fulfilled, and dead-surface ware was demanded and produced with unparalleled success. Dull surface was taken up by artists, and architects specified dead glaze for interior tilework as well as terracotta, and manufacturers all over the world sought to supply the need. (*Trans. A.C.S.*, vol. v. p. 50.)

Langenbeck, when referring to enamelled-tile work and decorative faience, observed that "The heavy glazes employed to make it decorative offend good taste, as well as make it practically impossible in manufacture to steer the product uniformly perfect through the 'Scylla and Charybdis' of crazing and shivering." (*Chemistry of Pottery*, p. 128.)

W. P. Rix asserts that "Strongly glazed tiles are open to much objection in obliterating the design by reflection." (*Jour. Soc. Arts*, 17.2.1893, p. 301.)

W. Burton, F.C.S., tells us:—"Demands have been made on us for some time by artists and architects of the newer school for glazes, especially those used on wall-tiles, that should not have the full brightness and glitter of ordinary pottery glazes." And again:—"Something was to be said for the production of dull glazes, particularly when it came to the question of wall-tiles. He confessed with Mr. Spiers that he had found the glitter of wall-tiles very distressing at times." (*Jour. Soc. Arts*, 22nd February 1901, p. 219.)

And the *Artist* lent its pages to the following:—"The brilliance of much of the work turned out in *grès flammes* had indeed become almost a weariness, and the nervous system gasps for a moment's rest. . . . . Sacheval, although he is not an art-tradesman, is coming round also to lower scales of colour. . . . . His most interesting pieces of pottery are certainly those in which he has subdued his colour and dulled his enamel. Nearly all his stoneware in *émail mat* is really remarkable. . . . . The enamel has no brilliance or sheen whatever." (*Artist*, January 1900, p. 267.)

Now, if one thing more than another has been claimed in favour of the use of lead compounds in ceramic glazes and enamels, it certainly is that "glossiness" is thereby developed. It follows, then, that if in certain cases glossiness is not desired, in those cases lead compounds surely may, appropriately, be dispensed with, particularly as they are admittedly injurious.

And if any difficulties are met with in the actual realization of this, let it not be forgotten that all is not smooth sailing with lead glazes:—"Those who produce matt glazes in a commercial way, state that the range of composition

and temperature within which they may be produced satisfactorily is exceedingly small." (*Trans. Am. Cer. Soc.*, vol. v. p. 230.)

But it is not necessary to theorize upon the possibility of an accomplished fact. Dull-surface leadless-glaze recipes, both colourless and of several choice tints, are included in this series; and for the rest, the inquiring reader will find learned discussions upon the nature of "matt" and of "crystalline" glazes in the *Transactions of the American Ceramic Society*, vol. v.; *Transactions of the North Staff. Ceramic Society*, vol. i.; in the *Pottery Gazette*, May 1903; in the *Journal of the Society of Arts*, 22nd February 1901; and in several German publications.

Cell Tolerance.—It is quite possible that differences of opinion as to the essential qualities of glazes may be more deeply rooted than they appear. Micro-lesions of the optical nerves, muscles, lenses, and all the marvellous and delicately balanced parts of the human means of vision may take place. In this way, the eyes of persons constantly engaged in the manufacture of or trading with thickly glazed tiles may eventually become so affected as to be unable to tolerate with pleasure the sensations conveyed from glazes with a purer, cleaner surface; and persons so affected may unconsciously be rendered incapable of appreciating the justice of the opinions of others whose optical sense has not been so prejudiced.

In like manner, those who accustom their palate to pungent irritating sauces cannot understand the refinement of perception that enables another person of simpler habits to distinguish delicate differences in taste between two nuts of the same class, or two oranges. Optical impressions are equally subtle; a person cannot gaze long at either bright yellow paper or bright red without distinctly perceiving that his sight has become disturbed. Hence it is within the range of possibility that a person may so accustom himself to look at lead glazes until he is incapable of justly appreciating leadless glazes, and so be unintentionally, perhaps, prejudiced against them.

Personally, the writer must confess to a greater pleasure in looking upon the cleaner leadless-glazed surfaces than upon many of the leaded glazes, because of a certain almost indefinable surface shimmer very frequently to be noticed on lead glazes.

Contemporary Glazes and Enamels.—In all discussions of this nature it should be borne in mind that not only "raw"-lead glazes, compounded in an old-fashioned way simply of white-lead, flint, and china-stone, are concerned; but also highly refined art-enamels skilfully prepared from boracic frits.

Hence the new lead-free compositions now struggling for their just place in the ceramic art are competing not merely with crude plumbiferous silicates, but with really elegant and advanced types of glazes.

For nearly a century boric acid compounds have been fastening them-

selves ever more firmly upon the British ceramic industry, and proving their superiority to lead compounds; and it would seem that the use of leadless glazes, such as are now frequently suggested for china-ware, flint earthenware, etc., would be little more than pushing the use of boric salts to its logical extreme.

Appended are a few comparisons of new and old glazes and frits, tabulated on a system suggested to the writer by Professor W. M. Flinders Petrie, F.R.S., namely, that of taking silica as a constant at 60 and calculating the proportions of the other ingredients on that basis. The few examples given will be sufficient to show the principle; the results place the proportion of lead salts in unexpected prominence, and at the same time demonstrate clearly the paramount position of silica in glazes generally.

COMPARATIVE PROPORTIONS BY WEIGHT WITH SILICA CONSTANT AT 60.

	SiO_2.	PbO.	Al_2O_3.	CaO.	Alk.	B_2O_3.
Soft tile-glaze for muffle, . . .	60	94·0	6·5	3·2	4·8	6·5
Raw-lead tile-glaze for muffle, . .	60	90·8	9·6	1·0	4·0	...
No. 3 glaze of Government Report, p. 28,	60	18·0	4·2	8·4	6·7	7·3
,, 4 ,, ,, ,,	60	14·9	6·4	4·9	8·5	3·1
Dr. Thorpe's insoluble silicate, Government Report, p. 37, ...	60	24·2	8·1	9·4	4·1	4·2
Minton's leadless glaze, Government Report, p. 40, ...	60	...	15·2	8·9	8·2	11·1
No. 1 frit of this chapter, . . .	60	...	11·0	12·5	17·0	22·5
,, 3 ,, ,, ...	60	...	9·8	15·0	12·0	23·5
,, 9 ,, ,, ...	60	...	12·2	13·0	12·0	13·5

Note.—The above figures have not been calculated with absolute exactness to a minute degree, but will be sufficiently indicative of the relations of the formulæ amongst themselves.

Volatility.—It has been assumed in some quarters that in the manufacture of the best class of wares the effect of certain gases presumed to be evolved by the lead salts in glazes during burning of the wares in the glost oven is indispensable, and that this is a characteristic of contemporary glazes wanting in the new leadless glazes.

It has not, within the writer's knowledge, been stated positively whether these gases were borates of lead or chlorides of lead, or indeed accurately determined what they are. But taking $PbCl_2$ as an example of a volatile salt of lead, it may be noted that its vapour density is about 9·6; therefore the rate of diffusion must often be slow and imperfect, and perhaps disposed to act in wreaths like heavy smoke.

Further, whatever action of this kind occurs, takes place within each saggar separately when closed, and is thus free from the influence of kiln draughts and any general air movements.

Nor has it been shown that the borates are not capable of supplying

equally powerful fumes. On the contrary, to quote our American friends, "It has been pointed out by Hottinger that boracic acid is a very volatile constituent, which not only escapes by volatilization, but is easily set free from its compounds by SO_3 in the kiln gas." (*Trans. Am. Ceramic Soc.*, vol. v. p. 306, vol. ii. p. 65, vol. iii. p. 180.)

Practical tests, by burning duplicate series of trials, some in lead-glaze washed saggars, and others in leadless-glaze washed saggars, have never, in the writer's experience, shown any superiority in favour of lead salts; and colours can be "flown" by leadless glazes of certain composition.

Influence of the Individual Ingredients.—In the few pages immediately following we purpose reviewing the respective influence of each of the principal elementary compounds entering into the composition of glazes. No words of our own can form a more fitting preface to these observations than those of Dr. Knapp, whose perspicuous comments upon the true nature of glass have fixed themselves upon our memory from early student days. They are, briefly, as follows:—

"It is well known that silica acts the part of a powerful acid at the temperature of a red heat, and is capable of expelling carbonic acid gas and hydrochloric acid, etc., from compounds, and combining with the bases . . . . giving rise to solid combinations. . . . . It is obvious that the properties of any kind of glass must be mainly dependent upon the nature of those bases which have been chosen for combining with silica in the process of fusion. The silicates of the alkalis are easy of fusion, and can consequently be produced at a moderately high temperature. They are, however, readily dissolved by water and decomposed by acids, and would, therefore, constitute by themselves a useless glass. The same applies, although in a lesser degree, to the silicates of the earths, as, for instance, silicate of lime. The oxides of the more weighty metals also—oxide of lead, for example, are easily attacked in this kind of combination by substances possessing some degree of affinity for the base. The corresponding compounds of alumina offer the greatest resistance to decomposing agencies. Whilst the former, the silicates of potash, soda, lime, lead, etc., almost invariably retain the amorphous state on cooling, the difficultly fusible silicate of alumina has a great tendency to acquire a crystalline structure, and this property unfits the glass for ordinary purposes. By combining the simple silicates with each other, however, experience has pointed out a method of compensation, or mutually destroying these conflicting properties, and producing a substance which neither loses its amorphous structure too readily, nor too easily suffers decomposi ion." (*Chemical Technology.*)

It will be necessary in every case to notice rather the reactions of the several ingredients upon other substances in more or less complex mixtures than the qualities of the ingredient itself alone. For just as we find strange

and powerful reactions taking place at temperature raised only slightly above the normal temperature, when intimate mixtures of certain ingredients are subjected to it; so, under the influence of higher temperature, we find other remarkable phenomena: thus, sand, chalk, and soda, when mixed and heated in a suitable manner, yield that lovely product glass; and, like an orchestra, as the performers increase in number and in the variety of their instruments, and higher planes of accomplishment are reached, more and more delightful compositions can be rendered, so with these vitreous compositions, as they become more complex by subtle admixtures, more and more pleasing effects become possible.

A chord is more pleasing than a single note or tone, a bar of music more delightful than a chord, a complete and full musical composition than a bar.

Dr. Seger, of Berlin, has left on record a classical series of experiments on lead-free glazes for earthenware. He tells us that protests had repeatedly been raised against the use of lead glazes owing to their poisonous properties, and that for many years he had been trying to do away with the poisonous lead oxide as a glaze material. The conclusion he arrived at he expressed briefly thus (Bleininger's translation):—"The lead glazes will still be necessary in all the branches in which the pottery requires an artistic treatment. However, the substitution will be possible in the glazing of whiteware, also of ordinary earthenware, that is, for plain-coloured or light whiteware, as well as those decorated with underglaze colours of the most various kinds."

Although this conclusion traverses in advance the claims the writer now makes with regard to high-class results in easily fusible coloured leadless glazes for tiles and decorative faience, it is, nevertheless, instructive to pick out a few examples from Dr. Seger's systematic and scientific method of investigating the problem, and in that way to note the manner in which the individual ingredients are believed to be brought into play in the production of a glaze.

He found that frits, made by the formula

$$\left.\begin{matrix} 0{\cdot}6K_2O(Na_2O) \\ 0{\cdot}4CaO \end{matrix}\right\} 2{\cdot}5SiO_2,\ 0{\cdot}5B_2O_3,$$

when ground with 0·1 of an equivalent of kaolin forming a glaze having the formula

$$\left.\begin{matrix} 0{\cdot}6K_2O(Na_2O) \\ 0{\cdot}4CaO \end{matrix}\right\} 0{\cdot}1Al_2O_3,\ 2{\cdot}7SiO_2,\ 0{\cdot}5B_2O_3,$$

melted at from silver-melting heat up to the temperature of fusion of an alloy of eighty parts silver and twenty parts gold to a clear and smooth coating of glaze that was found to be less injurious to underglaze colours than most lead glazes. The glaze adhered to hard-burned body very high in quartz (35 clay substance, 5 felspar, 60 quartz, burned between Cone 9 and 10). But that on a body higher in clay or burned softer the glaze crazed.

By doubling the proportion of added kaolin, and so securing a glaze of the formula

$$\left.\begin{matrix} 0{\cdot}6K_2O(Na_2O) \\ 0{\cdot}4CaO \end{matrix}\right\} 0{\cdot}2Al_2O_3,\ 2{\cdot}9SiO_2,\ 0{\cdot}5B_2O_3,$$

perfectly bright and glossy glazes were produced on rapid cooling, but they dimmed a little if cooled slowly in a tightly luted muffle.

This dimming was much more pronounced on a further increase of the added kaolin to 0·3 equivalent, and rendered the glaze unsuitable; but it was found possible to raise the silica content to 3·5 equivalents, by adding quartz, without injuring the glaze.

But he tells us (Bleininger's trans.) that "This proportion of alkali to lime, and this content of alumina and silica, must not be exceeded: for, on the one hand, the melting-point is thus raised, and reaches the allowable maximum in this composition; and, on the other hand, glazes containing much quartz not fritted in do not dissolve the latter, and do not fuse to a clear glass, but the quartz floats as a thin coating on the surface. If the content of alumina and silica is increased still more with a simultaneous increase of boracic acid, the fritting must be carried much higher, in order to dissolve the clay introduced. But this always produces more or less opaque glasses; while, as we will see later, with a less content of alkali and high proportion of lime, the introduction of much alumina leads to the production of clear and beautiful glasses."

Similar results were obtained with frits of the formula

$$\left.\begin{matrix} 0{\cdot}5K_2O(Na_2O) \\ 0{\cdot}5CaO \end{matrix}\right\} 2{\cdot}5SiO_2,\ 0{\cdot}5B_2O_3$$

when ground with 0·2 equivalent of kaolin. Pushing the displacement of alkali by lime still further, he tried a frit of the formula

$$\left.\begin{matrix} 0{\cdot}4K_2O(Na_2O) \\ 0{\cdot}6CaO \end{matrix}\right\} 2{\cdot}5SiO_2,\ 0{\cdot}5B_2O_3.$$

This opalined and dimmed; and while it formed a glaze when ground with 0·1 equivalent of kaolin, the glaze was opalined, and therefore unsuitable.

He then endeavoured to remove the milkiness and dimness of the glaze by increasing the content of boric acid. Against all expectation it was found that this course had the effect of making the dimming more pronounced.

When a frit like the preceding one was melted with the double amount of boric acid, a much more intensely dimmed glass-mass was obtained.

"For this reason," he tells us (Bleininger's trans.), "further attempts to produce glazes with frits free from alumina, or low in it, were not made, and only frits with a high content of alumina were employed, because these proved more successful."

A glaze of the composition

$$\left.\begin{matrix} 0{\cdot}2K_2O \\ 0{\cdot}2Na_2O \\ 0{\cdot}6CaO \end{matrix}\right\} 0{\cdot}3Al_2O_3,\ 4SiO_2,\ 1B_2O_3$$

was found to become dim. The cause of the dimness proved to be too low alumina contents, for the trouble disappeared on increasing the alumina.

The glaze became clear and staple with a composition of

$$\left.\begin{array}{l} 0{\cdot}2K_2O \\ 0{\cdot}2Na_2O \\ 0{\cdot}6CaO \end{array}\right\} 0{\cdot}6Al_2O_3,\ 5SiO_2,\ 1B_2O_3.$$

The melting-point of this glaze is somewhat below gold-melting heat. It was composed of:—

0·2	equiv.	potassium nitrate, ...	20·2
0·2	,,	crystallized borax, ...	38·2
0·6	,,	marble, ...	30·0
0·4	,,	Zettlitz kaolin, ...	51·8
4·2	,,	quartz-sand, ...	126·0
0·6	,,	hydrous boric acid, ...	37·2

The series of trials of glasses with an alkali-lime ratio of $0{\cdot}3K_2O : 0{\cdot}7CaO$, and of $0{\cdot}2K_2O : 0{\cdot}8CaO$, for various reasons, yielded no results applicable to the purpose Seger had in view at the time.

Another brilliant, well-devised, and patiently conducted series of investigations in this field of research is that by Professor Edward Orton, jun., of Ohio State University, Columbus, Ohio. Of this a full record is given in the *Trans. A.C.S.*, vol. v. p. 305–339, under the title, "On the Production of an Easily Fusible Glass without the Use of Lead or Boracic Acid."

The avowed object of these investigations was to enable Professor Orton to produce a series of ceramic pyrometric cones which will occupy the temperature range now covered by the Cremer series, but which will avoid wholly, or in part, certain defects enumerated in the paper.

The limitations imposed by the nature of the task brought down the available oxides to those of potash, soda, lime, magnesia, barium, zinc, alumina, and silica, with a possible addition of phosphoric acid. These substances were to be used in any form or proportion which would be likely to gain the end in view. But it was assumed to have been demonstrated that, with the preceding list of available ingredients, no raw or unfritted mixture fusing at a melting-point of Cone 010 or 950° C. can be made; and that, excluding BaO, no glaze can be made from the others which fuses below Cone 1, without resorting to other sources of alkali than felspar, which is impractical in cone manufacture. Hence fritting was accepted as an essential expedient.

The first experiment was based roughly on the formula

$$\left.\begin{array}{l} 0{\cdot}3Na_2O \\ 0{\cdot}7CaO \end{array}\right\} 0{\cdot}3Al_2O_3,\ 2{\cdot}10SiO_2,$$

and the batch-weights are given as:—

41·8 of powdered window glass.
13·7 of calcined bone.
25·8 of kaolin.

The ingredients were intimately ground together, dried, mixed with dextrine paste, molded into test-cones, with the result that this glass-bone-kaolin mixture was found to fuse a little later than Cone 1, probably about Cone 2.

"This single test," he tells us, "at once dispelled any hopes of being able to utilize bone as a vigorous aid in low-temperature work."

A series of six other experiments, of which glass formed the foundation, led the professor to the conclusion that "No help was to be expected from common glass as a flux, at temperatures much below where feldspar becomes available."

He therefore formulated a series of experiments, with the object of discovering whether common glass represented the most fusible silicate which can be made from soda, lime, and silica. He mixed two batches as follows:—

1–H (common window-glass formula) consisted of:—

53 parts of common soda-ash (Na_2CO_3).
50 ,, Paris white.
150 ,, potter's flint.

And No. 1–M. consisted of:—

53 parts of common soda-ash.
50 ,, Paris white.
30 ,, flint.

From these two extremes four glass batches were prepared by blending, and the mixtures melted. The resulting fused masses were separately powdered, and cones made by mixing the glass-dust with dextrine paste and molding, as usual, in steel molds.

Tests were made, and though adversely affected by accidents of process, and not wholly satisfactory, it was presumed to have been ascertained that the mixture of

3 parts of 1–H
1 ,, 1–M

was probably the softest resulting glass of the series.

In pursuing other series of tests the usual accidents and disappointments of the experimenter were met with, and the not altogether new sensation of finding that ascertained facts were sometimes at variance with generally accepted ideas.

At the end of the sixth series of experiments, he tells us that the net results of the inquiry stood thus:—

(1) Using one-half molecule each soda and lime, 2·00 molecules of SiO_2, makes the most fusible glass producible.

(2) Diminishing the lime and increasing the soda to

$$\left.\begin{array}{l}0{\cdot}7Na_2O\\0{\cdot}3CaO\end{array}\right\} 2{\cdot}00SiO_2,$$

the melting-point falls from 1169° to 980° in one test, and from 1075° to 925° in another, or a net gain of over 150° C. But owing to doubts about the stability of a glass so high in alkali, it was deemed wiser to use 2–B,

$$\left.\begin{array}{l} 0{\cdot}60Na_2O \\ 0{\cdot}40CaO \end{array}\right\} 2{\cdot}00SiO_2,$$

as the basis of further tests. This glass had melted in the last burn, practically with Cone 010.

Nevertheless, it was desirable to pursue the investigation further, because, to enable a suitable pyrometric cone to be made, a large dilution of the basal frit was needed to secure gentle and uniform fusion. A glass melting fully 200° C. below Cone 010 was wanted.

It was therefore determined to try the effect of substitution of potash for soda, and also of the two alkalies conjointly. Accordingly the following (series 7) glasses were made:—

2–T glass ($0{\cdot}6K_2O$, $0{\cdot}4CaO$, $2{\cdot}00SiO_2$).
2–U ,, ($0{\cdot}6Na_2O$, $0{\cdot}4CaO$, $2{\cdot}00SiO_2$).
2–F ,, ($0{\cdot}3K_2O$, $0{\cdot}3Na_2O$, $0{\cdot}4CaO$, $2{\cdot}00SiO_2$).

"These were made up from potassium carbonate (c.p.), soda-ash (commercial), whiting, flint; were fused in cups to Cone 8; and were then broken, sorted, crushed, put through 100-mesh sieve, and made into cones as before."

Upon testing, the fusion temperatures were as under:—

2–T.	Potash-lime glass, ...	945° C.
2–U.	Soda-lime glass, ...	925° C.
2–F.	Potash-soda-lime glass, ...	890° C.

Professor Orton significantly adds:—"The point seems clear that the mixture of two alkalies is better than either alone. This point is well known in other connections, viz., in fluxing in platinum crucible in the chemical laboratory. . . . . But so many contradictions had been met so far since undertaking this work, that it was thought best to take nothing for granted, and to prove each point as we came to it."

The next series comprised glasses in which the lime was replaced by other bases, thus:—

2–F. $0{\cdot}3K_2O$, $0{\cdot}3Na_2O$, $0{\cdot}4CaO$, $2{\cdot}00SiO_2$.
2–G. $0{\cdot}3K_2O$, $0{\cdot}3Na_2O$, $0{\cdot}4MgO$, $2{\cdot}00SiO_2$.
2–H. $0{\cdot}3K_2O$, $0{\cdot}3Na_2O$, $0{\cdot}4BaO$, $2{\cdot}00SiO_2$.
2–I. $0{\cdot}3K_2O$, $0{\cdot}3Na_2O$, $0{\cdot}4ZnO$, $2{\cdot}00SiO_2$.

Of these Professor Orton says:—"The glasses resulting from this fusion were all of excellent quality. The calcium glass was the least brilliant of the lot, and the zinc and barium glasses were of especially high refractive index, and therefore brilliant to the eye. In fusion the barium glass fused first, and the calcium glass last; but this could not be accepted as evidence of the fusibility of the glasses when once formed, though of course it gives us a basis for expectation.

"On putting these through the usual procedure of grinding, fusion, sorting, regrinding, cone molding, and firing, the following figures were gotten :—

2–F.	Lime glass,	890° C.,	time 6 : 36
2–G.	Magnesia glass,	755° C.,	,, 4 : 42
2–H.	Barium glass,	880° C.,	,, 6 : 29
2–I.	Zinc glass,	755° C.,	,, 4 : 42

"These figures alone fail to accurately represent the facts, because the fusion of a glass is often a slow process, and a cone may begin to soften and bend a long time before it actually fuses, and uncertainty arises as to which may be fairly considered having fused. . . . . This evidence is undoubtedly somewhat confusing. The only thing which is beyond doubt is that the glass

$$\left.\begin{matrix} 0{\cdot}3K_2O \\ 0{\cdot}3Na_2O \\ 0{\cdot}4CaO \end{matrix}\right\} 2SiO_2$$

is the least fusible of any of the four under test."

In the ninth series still more complex glasses were tried, using two or more of the bases together, in accordance with the following formulæ :—

No. of Glass.	Molecular Composition.						
	K_2O.	Na_2O.	CaO.	MgO.	BaO.	ZnO.	SiO_2.
2–J,	0·3	0·3	0·2	0·2	...	...	2·00
2–K,	0·3	0·3	0·2	...	0·2	...	2·00
2–L,	0·3	0·3	0·2	...	...	0·2	2·00
2–M,	0·3	0·3	...	0·2	0·2	...	2·00
2–N,	0·3	0·3	...	0·2	...	0·2	2·00
2–O,	0·3	0·3	...	...	0·2	0·2	2·00

"In this series the K_2O, Na_2O, SiO_2 were weighed out and ground intimately together as one batch, and then divided into small portions, into the which proper quantities of the two remaining oxides were then added and ground in. The melts resulting were all clear, brilliant, handsome glasses, any of which seemed perfectly suited to the usual uses Those in which barium and zinc were used were brighter than the others perhaps. . . . . It was noted in watching the glasses fusing that 2–M was considerably in advance of any other in fusing."

Results of testing as cones were as under :—

2–J,	755° C.,	time 5 : 35
2–K,	800° C.,	,, 5 : 55
2–L,	780° C.,	,, 5 : 45
2–M,	705° C.,	,, 5 : 20
2–N,	755° C.,	,, 5 : 35
2–O,	575° C.,	,, 4 : 45
Cone 010,	945° C.,	,, 7 : 22

For various reasons—given in the text—Professor Orton found it difficult to fairly evaluate the comparative results of the foregoing; but he tells us that "None of the glasses containing calcium fuse as readily as those in which it is absent"; that is, of course, in the above series of tests.

Continuing, the learned professor says:—"To still further probe the matter of the effect of mixture of RO elements, another series, No. X., was prepared as follows:—

No. of Glass.	Molecular Composition.						
	Na_2O.	K_2O.	CaO.	MgO.	BaO.	ZnO.	SiO_2.
2–P,	0·3	0·3	0·13	0·13	0·13	...	2·00
2–Q,	0·3	0·3	0·13	0·13	...	0·13	2·00
2–R,	0·3	0·3	...	0·13	0·13	0·13	2·00
2–S,	0·3	0·3	0·10	0·10	0·10	0·10	2·00

"On fusion these produced handsome, brilliant glasses of high refractive index. Especially noteworthy was 2–R, which had a delicate bluish cast, and a beautiful, limpid, yet brilliant appearance. On making into cones and testing they showed as follows:—

No. of Glass.	Fusion began.		Fusion completed.	
	Time.	Temp.	Time.	Temp.
2–P,	4 : 14	725° C.	4 : 21	735°
2–Q,	4 : 14	725° C.	4 : 37	795°
2–R,	4 : 14	725° C.	4 : 30	775°
2–S,	4 : 08	700° C.	4 : 26	755°
Cone 010,	5 : 10	880° C.	5 : 16	910°

Of these Professor Orton trenchantly observes:—"These results seem perfectly decided and unimpeachable, whatever we may think of their rationality."

Summarizing, he remarks:—"It has been shown (*a*) by reduction of SiO_2 from 2·50 to 2·00 molecules, (*b*) by increase of alkali from 0·5 to 0·6 molecules, (*c*) by use of $0·3K_2O$ and $0·3Na_2O$ in place of 0·6 of either alone, (*d*) by replacement of CaO, either wholly or very largely, with MgO, BaO, or ZnO, or mixtures of these, that a large variety of glasses have been produced, which soften at about 650°, and melt at 750°, while Cremer Cones 010 placed in the same test melt from 875 to 925°. Common window glass required in another burn Cone 02 before fusion, in which the pyrometer showed the abnormally high temperature of 1155°. It is not likely that the figures are strictly comparable, but at least there is no doubt that the glasses produced at the close melted fully 350°, and possibly 400° below the common window glass first tested. . . . . We have now not one but many glasses, any of which fuse 150 to 200° below Cone 010, and so far as mere fusibility is

concerned, could be used as the basis of a Cone 010 mixture. Also the progress has been attained without recourse to any but non-reducible oxides, as originally planned." (*Trans. American Ceramic Society*, vol. v. p. 330.)

Although the foregoing investigation had a different object than that of which this volume treats, the bearing is in the same direction. Professor Orton has indirectly rendered valuable service to the cause of leadless glazes, and his results will form the basis of much further experimenting. He has demonstrated more perhaps than any individual can single-handed ever fully practically apply; for he has demonstrated not only that leadless glasses can be prepared having melting-points at temperatures below the lowest heats usually attained in majolica glazed-ware kilns, but that, without the aid of either lead salts or boric acid, glasses melting at the heat of ceramic enamel colours are producible. He thus opens the door for a very wide field of further ceramic research, and greatly helps the advocacy of non-plumbic glazes and enamels.

Influence of Boric Acid in Glazes.—In formulating glazes for application to decorative tiles and faience, it is not only necessary to consider what produces a smooth glassy glaze at a sufficiently low temperature, but also what will withstand, in the form of glaze, the attacks of the atmosphere, varying in seasons and localities, and in nature and activity of the chemical affinities concerned. In such cases, obviously, warnings emanating from trained observers deserve close attention.

With regard to borates, Mr. H. H. Cunynghame, C.B., has written:—"Borates are as a rule fusible and exceedingly hard—that is to say, they will generally scratch glass. Glass made with borax also unites easily with metallic oxides, and hence takes colour well, and also causes the glass to become very liquid and flow easily. It is therefore often used to make fusible enamels. But it has two defects. In the first place, enamels made with it are liable to crack, and are deficient in elasticity; and, in the next place, they are very susceptible to moisture. . . . .

"More church windows have suffered from rain through the use of borax than from any other cause, and there is no need to employ it, as perfectly good enamel can be made without it. In fact, its only use is to combine fusibility with a hard surface; and as there is no need for making a Limoges enamel with a very hard surface, the necessary fusibility can be better obtained by means of lead." (*Art Enamelling on Metals*, p. 158.)

It is just possible Mr. Cunynghame based his assertions partly upon those of Professor Barff (see *British Manufacturing Industries*, pp. 116–118), or, at anyrate, was influenced by them, and did not go behind him to discover that durable enamels can be made even when borates enter into the composition, provided the mixture is judiciously proportioned and of suitable constituents.

Although these warnings render it necessary to re-examine recipes and

theories, reweigh facts, and look round for other opinions and evidence, based upon equally substantiated experiences, they are, nevertheless, most valuable as an incentive to thorough and careful research.

The influence of borates in glazes may be studied, in the first place, by reference to the several reports of commissions of inquiry on plumbism in potteries. Turning to the *Report to Her Majesty's Principal Secretary of State for the Home Department on the Conditions of Labour in Potteries, the Injurious Effects upon the Health of the Workpeople, and the Proposed Remedies*, by the Potteries Committee of Inquiry, which sat at Stoke-upon-Trent in May and June 1893, we find that Mr. A. P. Laurie, M.A., B.Sc., F.R.S.E., made a series of experiments with frits and glazes, some containing borates and others not containing borates; his conclusions, as expressed on pp. 10 to 12 and 23 to 27 of the report, are subjoined, and are referred to at considerable length, because at the time of writing this particularly valuable report is out of print.

"REPORT ON THE PROPERTIES OF LEAD FRITTS.

"It is customary in making up the glaze for pottery ware to add a considerable quantity of white-lead or red-lead. The white-lead is more commonly used, and is recognised as being a very poisonous lead preparation, on account of its easy solubility in the juices of the stomach. Now, it also is usual to add to the glaze a certain amount of 'fritt,' that is, of constituents fused at a high temperature into a rough glass; and it has been suggested that if all the lead required was fused up in this fritt, it would then exist in a practically harmless form. Some important evidence was brought before the Committee, tending to show that such fritts were harmless, and it therefore seemed of importance to examine how far the lead in these fritts could be regarded as being present in a form insoluble in the stomach. I was therefore requested to apply certain tests with the view of throwing further light on the question. I therefore obtained samples of fritts in actual use, and submitted them to examination. In applying the tests I have been guided by the experiments published by Dr. Oliver in his work on lead poisoning. He there describes experiments showing that carbonate of lead is soluble both in the gastric juice and the bile, and he further proves that the active agent in the gastric juice is the free hydrochloric acid it contains, the pepsine exerting no influence. I decided, therefore, to experiment on these fritts, both with bile and with weak solutions of hydrochloric acid, with a view to testing their solubility.

"The first glaze I selected was some supplied to me by a manufacturer out of the dipping-tub. It had therefore been very finely ground in water, thus rendering it more liable to be dissolved, and it consisted of a mixture of flint and stone, with two fritts, one containing about 16 per cent. of lead and the other 30 per cent. of lead. I repeated with this material the experiments made by Professor Bedson for Dr. Oliver on carbonate of lead, treating it

with bile in a 'diffusion tube' for several hours at a temperature of 100° F. to 110° F., without dissolving out any trace of lead; thus showing that the lead it contained was not soluble in bile.

"My next experiment was to treat it with weak hydrochloric acid. I found it necessary, however, to wash it first with water, as the water it was mixed with was strongly alkaline. After washing and drying, I treated 1 gramme with 50 c.c. of hydrochloric acid containing ·3 per cent. of acid. I selected this strength of acid partly because it had been used by Dr. Oliver in his experiments, and partly because I thought it advisable to use an acid rather stronger than that present in the stomach, as the conditions for solution are probably much more favourable in the stomach than in a laboratory experiment. I found that on digesting for some time at 100° F. a considerable quantity of lead had been dissolved. Evidently, then, these fritts were not insoluble in weak acid, as I had hoped, and it became necessary to determine to what extent they were soluble as compared with other lead compounds.

"I therefore determined to test them under similar conditions against a substance to be taken as a standard of solubility, and I selected for this purpose sulphate of lead. This substance is regarded by the medical profession as practically innocuous, because of its insolubility. It is, however, slightly soluble in weak acid, though apparently not to a serious extent.

"In each case 1 gramme of the substance was treated for three hours at 100° F. with 50 c.c. of ·3 per cent. hydrochloric acid. There was thus a large excess of free acid present, and the time and temperature corresponded roughly with the digestive process. The results were as follows:—

Material used.	Percentage of Raw Lead put in Fritt.	Percentage of Borax put in Fritt.	Percentage of Metallic Lead dissolved from 100 Parts of the Material used.	Percentage of the whole Amount of the Lead present in the Material which was dissolved.	Remarks
Lead sulphate,	...	...	1·21	1·77	
Glaze from dipper's tub made up of two fritts,	not known	not known	6·67	...	A mixture of fritts No. 1 and No. 2 with flint and stone.
Fritt No. 1,	16·0	28·8	5·41	33·8	
Fritt No. 2,	30·0	10·7	1·13	3·7	This fritt analysed and found to contain 30·3 per cent. of lead.
Majolica fritt,	60·0	none	7·78	12·9	This fritt is a silicate of lead free from borax.
Fritt No. 3,	28·9	not known	5·61	21·6	Analysed, and 26 per cent. of lead found.
White lead,	...	...	41·23	...	That is, the acid dissolved the carbonate until saturated. More acid would have taken up more carbonate.
Seven grammes of a common teacup ground up,	...	...	0·21	...	

"On examining this table it is obvious that all these fritts are much better than raw lead, being much less soluble in weak acid, and therefore less dangerous to introduce into the stomach. On the other hand, they differ a good deal in solubility, and are in most cases more soluble than lead sulphate. The solubility in acid evidently depends on two things, an excess of lead and an excess of borax. For instance, the majolica fritt, while free from borax, and containing nothing but the much more insoluble silicates of lead, but with a large quantity of lead present, dissolves to the extent of nearly 8 per cent.

"On the other hand, if No. 1 and No. 2 fritts are compared, it is evident that, although No. 2 had double the amount of lead, it is less soluble; while No. 1, with half the amount of lead, but three times the amount of borax, is more soluble.

"It is therefore evidently of importance, in order to obtain a perfectly safe fritt, to limit the amount of borax as well as of lead in the fritt.

"While, therefore, fritting the lead no doubt diminishes the danger of lead poisoning for the workers, yet we cannot regard all fritts as equally innocuous; nor could we assume any fritt to be as harmless as lead sulphate, without first examining how far it is soluble in weak hydrochloric acid." (*Report*, pp. 10, 11, and 13.)

"APPENDIX K.

"In my first report on fritts (p. 10), I pointed out that the solubility of the lead in weak hydrochloric acid depended both on the amount of lead present and on the amount of borax present in the fritt. With a view to determining, with such exactness as was possible, what were the limits within which borax and raw lead might be added to a fritt, I asked Mr. G. G. Leason, of Minton's Limited, to prepare a set of experimental fritts containing varying quantities of borax and white-lead, along with Cornish stone, sodium carbonate, flint, and whitening. These fritts, after being made, were ground in the usual fashion and sent to me by Mr. Leason, ready for the dipping-tub. The following table shows the percentage of borax and white-lead contained in these fritts:—

Number, . . .	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Borax, . . .	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
White-lead, . .	10	10	10	20	20	20	30	30	30	40	40	40	50	50	50

"A gramme of each of these fritts was treated with ·38 per cent. hydrochloric acid for three hours at from 100° F. to 110° F. At the same time

some sulphate of lead was treated in the same way as a check experiment. The amount of sulphate of lead dissolved was ·9 per cent., being practically the same as the amount dissolved in the former experiments.

"On estimating the amount of lead dissolved from each of these fritts, the conclusions of my previous report were confirmed in a remarkable manner, the amount of lead dissolved varying both with the amount of lead present in the fritt and the amount of borax present in the fritt.

"These results are clearly shown in Table 2. Along the top of the table are placed the percentages of raw lead in the fritt, and down the side of the table the percentages of borax in the fritt. Consequently, in order to find any fritt mentioned in Table 1, it is only necessary to draw a line down Table 2, starting from the percentage of raw lead it contains, and along Table 2, starting from the percentage of borax it contains, to find the square corresponding to that fritt.

"On looking at Table 2 it will be obvious at once that the amount of lead dissolved increases horizontally with the increase of the amount of lead present, and increases vertically with the amount of borax present.

"We may probably assume for the present, until further light is thrown upon this question by the medical authorities, that fritts in which less than 3 per cent. of lead is dissolved are practically harmless; all such fritts have been printed in heavy type in Table 2.

TABLE No. 2.

Percentages of Borax in Fritt.	Percentages of Raw Lead in Fritt.				
	10	20	30	40	50
	Percentages of Lead dissolved.				
10	**·3**	**·5**	**2·8**	5·0	12·0
20	**·6**	**2·4**	5·0	13·0	15·0
30	**1·3**	6·0	14·0	20·0	36·0

NOTE.—In the use of fritts in which the percentage of lead and borax added together amount to 60 and upwards, some of the lead chloride formed separates slowly in working, and in the fritt containing 50 of lead and 30 of borax the acid is saturated.

"On comparing these fritts one with another, we find that we can sum up the results of the inquiry in a very simple rule, viz.:—*If the percentage of raw lead and the percentage of borax in a fritt do not amount, when added together, to more than 40, the fritt may be regarded as practically harmless; but if the per cent. of lead and the per cent. of borax, when added together, amount to more than 40, the fritt is probably too soluble to be safely used.*

"It would be interesting to know whether manufacturers of fritts consider this limit practicable for ordinary glazes. It will be noticed at once that this

rule would not include majolica fritts, and that therefore, while doubtless majolica fritts are far less dangerous to use than raw lead, it would be a great mistake to regard them as non-poisonous. . . . . I need hardly say that I regard this standard merely in the light of a temporary working hypothesis, the ultimate justification of which must depend upon medical evidence. . . . ." (A. P. LAURIE, *Report*, pp. 10–12, 23–24.)

Turning now to the elaborate series of experiments on the solubility of glaze frits conducted by Professor T. E. Thorpe, LL.D., F.R.S., and described in the *Report to Her Majesty's Principal Secretary of State for the Home Department on the Employment of Compounds of Lead in the Manufacture of Pottery*, dated 21st February 1899, we find that these considerably qualify Mr. Laurie's findings in respect of the influence of borax on solubility, and at the same time indirectly traverse the assertions of Professor Barff and Mr. H. H. Cunynghame, C.B. Dr. Thorpe's results clearly prove that there have been in actual use in the trade certain fritted silicates of lead in which neither borax nor borates occurred, and which were supposed to be beneficial, but upon testing were found to yield up, when digested in acidulated water, practically the whole of their contained lead compounds. The descriptive table on p. 28 of the report, a copy of which table we subjoin, shows the frits to have yielded up respectively 98·3, 95·6, 99·6, 99·6 per cent. of lead oxide; this, be it observed, in entire absence of borates.

AMOUNTS OF LEAD OXIDE DISSOLVED FROM SAMPLES 1 AND 2 OF OWEN'S LEAD SILICATE.

Compound	Weight of Compound used.	Weight of Lead Oxide present.	With ·25 per cent. HCl, 100 c.c. = ·760 gram PbO.		With ·05 per cent. HCl, 100 c.c. = ·152 gram PbO.		With ·05 per cent. HAc, 100 c.c. = ·092 gram PbO.	
			LEAD OXIDE DISSOLVED					
			(1) From equal Weights of the Lead Compounds.					
			Weight.	Percentage.	Weight.	Percentage.	Weight.	Percentage.
No.	Grams.	Grams.						
1	·1	·0712	·0700	98·3	·0625	87·8	·0453	63·6
2	·1	·0704	·0673	95·6	0614	87·2	·0431	61·6
			(2) From proportionate Weights containing equal Quantities of Lead.					
1	·070	·050	·0498	99·6	·0500	100·0	·0377	75·4
2	·071	·050	·0498	99·6	·0496	99·2	·0366	73·2

Chemical analysis { No. 1. Silica, 22 per cent ; lead oxide, 71·2 per cent.
No. 2. Silica, 25·11 per cent. ; lead oxide, 70·4 per cent.; alkalis, 1·91.

Two other frits were examined by Dr. Thorpe, which were also free from borates; the chemical analysis of these is given in full on p. 29 of the report, thus:—

	No. 5. Lead Fritt from Doulton's (fritted with Flint, China-clay, etc.).	No. 6. Owen's Lead Silicate (fritted with Alumina and Alkalis).
Silica, ...	37·62	35·66
Lead oxide, ...	37·92	45·77
Alumina, ...	8·24	10·04
Lime, ...	10·83	1·16
Magnesia, ...	0·08	0·14
Alkalis, ...	3·72	7·09
	98·41	99·86

When the solubility of these was determined, it proved to be respectively: No. 5, 73·8 and 60·4; No. 6, 23·5 and 23·8, as per copy of table on p. 30 of the report, thus:—

AMOUNTS OF LEAD OXIDE DISSOLVED FROM SPECIMENS 5 AND 6.

Compound.	Weight of Compound used.	Weight of Lead Oxide present.	With ·25 per cent. HCl, 100 c.c. = ·760 gram PbO.		With ·05 per cent. HCl, 100 c.c. = ·152 gram PbO.		With ·05 per cent. HCl, 100 c.c. = ·092 gram PbO.	
			LEAD OXIDE DISSOLVED (1) From equal Weights of Lead Compounds.					
			Weight.	Percentage.	Weight.	Percentage.	Weight.	Percentage.
No.	Grams.	Grams.						
5	·1	·0379	·0280	73·8	·0172	45·4	·0052	13·7
6	·1	·0458	·0108	23·5	·0097	21·2	·0015	3·3
			(2) From proportionate Weights containing equal Quantities of Lead.					
5	·132	·050	·0302	60·4	·0237	47·4	·0047	9·4
6	·109	·050	·0119	23·8	·0113	22·6	·0016	3·2

Thus, again, we observe a very marked difference in solubility totally irrespective of any influence by borates, the presence of 10 per cent. lime more in No. 5 than No. 6 being the chief difference; and No. 6 having double the per cent. of alkalis. This is particularly well worth noting, for one would naturally rather have expected the reverse, viz., that plumbic alkaline fritts would have been more soluble than plumbic alkali-alkaline earth fritts. This certainly is most valuable information, and, moreover, it has long ago been

observed by mineralogists that lime felspar is more easlly decomposed by atmospheric influences than potash felspar. (See p. 31, *Researches on Leadless Glazes.*)

There is a further fact, also well known, viz., that Bohemian or potash-lime glass is the one least acted upon by chemical reagents, whilst flint glass, *i.e.*, potash-lead glass, is easily attacked by chemical reagents. (See p. 21, *Researches on Leadless Glazes.*)

Hence, perfectly apart from any influence of borates, the foregoing plainly shows that both plumbic silicates and calceo-plumbic silicates are easily attacked by acidulated water in a very attenuated condition of dilution; by inference, they will also be easily attacked by the humid acidulous atmosphere generally prevailing in many cities and large towns, besides being subject to filming of the surface on account of the presence of sulphurous fumes in air arising from the vast consumption of pit coal.

Whatever Professor Barff and Mr. H. H. Cunynghame, C.B., may have said about borax and borates, it seems that the "pot is as black as the kettle." Lead compounds have equal defects; indeed, that eminent and accomplished American expert, Langenbeck, has written:—"The hard alkali-alkaline earth glazes are far the best for resisting atmospheric influences."

The further tabulated results of Professor Thorpe's experiments (p. 31 of the *Report*) in like manner show that, irrespective of the proportion of boracic acid present, a greater percentage of alkalis in a fritt favours solubility in weakly acidulous water. But these tables also show what is very much more to the point, namely, that the presence of boracic acid in the fritts Nos. 7, 8, and 9 (p. 30 of the *Report*) was concurrent with an enormously reduced solubility of the contained lead, as compared with that of fritts Nos. 5 and 6, which were free from boracic acid.

The actual tables are as under:—

CHEMICAL COMPOSITION.

	Owen's Finished Glaze Fritt (all the materials fritted). No. 7.	Fritt from Boch Frères. No. 8.	Fritt from La Société Céramique. No. 9.
Silica,	49·67	52·94	53·16
Lead oxide,	16·23	22·44	18·97
Alumina,	10·34	7·62	8·06
Lime,	8·54	8·82	8·96
Magnesia,	0·19	0·12	0·11
Alkalis,	9·20	3·99 [1]	4·86
Boracic acid,	5·83	3·82	5·88
	100·00	99·75	100·00

[1] Sodium oxide = 2·35; potassium oxide = 1·64.

AMOUNT OF LEAD OXIDE DISSOLVED FROM FRITTED GLAZES 7, 8, AND 9.

Compound.	Weight of Compound used.	Weight of Lead Oxide present.	With ·25 per cent. HCl, 100 c.c. = ·760 gram PbO.		With ·05 per cent. HCl, 100 c.c. = ·152 gram PbO.		With ·05 per cent. HAc, 100 c.c. = ·092 gram PbO.	
			LEAD OXIDE DISSOLVED (1) From equal Weights of Lead Compounds.					
			Weight.	Percentage.	Weight.	Percentage.	Weight.	Percentage.
No.	Grams.	Grams.						
7	·1	·0162	·0017	10·5	·0014	8·6	·00026	1·6
8	·1	·0224	·00065	2·9	·0006	2·6	·00020	·9
9	·1	·0190	·0012	6·3	·0011	5·7	00027	1·4
			(2) From proportionate Weights containing equal Quantities of Lead.					
7	·309	·050	·0033	6·6	·0026	5·2	·00043	·9
8	·223	·050	·0013	2·6	·0012	2·4	·00047	·9
9	·264	·050	·0028	5·6	·0026	5·2	·00065	1·3

The astonishing comparison of results from the tests on proportionate weights containing equal quantities of lead then appear to be as follows:—

No. 5, ...	60·4	No boracic acid present.
,, 6, ...	23·8	
,, 7, ...	6·6	Boracic acid present.
,, 8, ...	2·6	
,, 9, ...	5·6	

May we not now ask, IN WHAT RESPECTS DO BORATES FALL SHORT? What ground is there for the assertions by Barff and Cunynghame?

Dr. Thorpe summarized his results in the following terms:—

"1. The lead compounds tested fall into four classes:

"(*a*) Oxides of lead.

"(*b*) Simple so-called 'lead silicates,' consisting essentially of lead oxide and silica, with only small amounts of alumina, lime, and alkalis.

"(*c*) Finished glazes, in which the 'lead silicate' of (*b*) has been introduced as a substitute for white-lead by simple admixture, *i.e.*; without fusion.

"(*d*) Double or complex silicates and boro-silicates, in which the lead oxide has been fused not only with silica, but also with alumina, lime, and alkalis in quantity.

"2. Of these compounds, none of those comprised in classes (*a*), (*b*), and (*c*) was found to offer any appreciable advantages over white-lead in the matter of solubility. The whole, or approximately the whole, of the lead is dissolved out when the acid is in sufficient excess.

"3. With the complex silicates of class (*d*), the extent of the solvent action depends upon the composition of the silicate. Some specimens in actual use by potters have been examined, and found to yield only nominal quantities of lead to the action of the solvents. The composition of the most stable of these specimens is:—

Lead oxide,	22·44	per cent.
Silica,	52·94	,,
Alumina,	7·62	,,
Lime,	8·82	,,
Magnesia,	0·12	,,
Alkalis,	3·99	,,
Boric anhydride,	4·07	,,
	100·00	

"4. From this fritt a boro-silicate has been prepared, differing from it but slightly in the proportions of the constituents, but which is practically not attacked at all by the acids used. The composition of this insoluble compound is:—

Lead oxide,	21·83	per cent.
Silica,	54·44	,,
Alumina,	7·43	,,
Lime,	8·54	,,
Magnesia,	0·12	,,
Alkalis,	3·80	,,
Boric anhydride,	3·84	,,
	100·00	

"5. It seems highly probable that fritts of the character described in 3 and 4 will serve most if not all of the manufacturers' purposes as a form in which the lead may be introduced to make the finished glaze, and that their sparingly soluble nature will render them in a great measure harmless, though perhaps not entirely so." (*Report to H.M. Principal Secretary of State*, *etc.*, *etc.*, p. 37.)

For the use of a client the formula for insoluble frit, as recommended by the Government chemist, was subsequently written out in terms customary to practical potting processes, thus:—

FRIT.	GLAZE.
25 lbs. white-lead carbonate.	180 lbs. frit.
55 ,, ground silica.	18 ,, china-clay.
8 ,, alumina (calcined).	
17 ,, carbonate of lime.	
15 ,, borax.	

When the preliminary experimental trial of this frit was submitted in the Government laboratory to the prescribed test for solubility—viz., "A weighed quantity of dried material is to be shaken for one hour, at the common temperature, with one thousand times its weight of an aqueous solution of hydrochloric acid containing 0·25 per cent. of HCl. This solution is thereafter to be allowed to stand for one hour, and to be passed through a filter. The lead salt contained in an aliquot portion of the clear filtrate is then to be precipitated as lead sulphide and weighed as lead sulphate"—it yielded only 1·5 per cent. lead oxide. And when, twelve months later, specimens of the ware dipped in the glaze above described were examined, they were found to be quite sound and free from crazing. The glaze was slightly too "hard." It suited U.G. matt-blue colour admirably, but injured U.G. pink and U.G. pheasant colour. No doubt, by a reduction of the china-clay and some slight alterations in the formula of the frit, these defects could be remedied without seriously affecting its solubility.

Another more fusible composition, tested concurrently, proved of brighter surface, but this also injured U.G. pink and U.G. pheasant; claret-brown, however, was remarkably good under it. The frit of this glaze showed 1·7 per cent. solubility by the Government test.

In each of these borax had been used in the frit; yet, upon testing, a solubility of only 1·5 per cent. and 1·7 per cent. respectively of the lead oxide was found; whereas it has already been shown that silicates of lead perfectly free from boric acid are, in some instances, so soluble that "approximately the whole of the lead is dissolved out when the acid is in sufficient excess."

Further testimony to the utility of borax in ceramics may be found in the references to it by experts, thus:—

"Borax is of the greatest importance in glaze composition. . . . Its use in glazes makes them harder in surface and more brilliant."—Prof. C. F. BINNS. (*Ceramic Technology*, p. 70.)

"Borax . . . . on account of its great purity, is used in almost every flux, and is of great service for those colours which, like the pinks and purples, would suffer from the presence of lead."—J. F. L. ARNOUX. (*British Manufacturing Industries*, p. 43.)

"Without the use of some borax it is almost impossible to get a fusible and yet brilliant white."—H. H. CUNYNGHAME, C.B. (*Art Enamelling upon Metal*, p. 180.)

"The action of boracic acid is similar to that of quartz or silica in changing the coefficient of expansion in opposition to the effect of the bases, but the melting-point does not rise in the same proportion. On the contrary, by the substitution of silica with boracic acid, the melting-point falls very materially."—KARL LANGENBECK. (*Chemistry of Pottery*, p. 50.)

"When boracic acid is added, it forms boro-silicates, often more fusible, more ductile, easier to work, and producing less waste, especially in table-ware and plate-glass manufacture." — MUSPRATT. (*Chemistry Applied to Arts*, p. 190.)

There are, of course, limits to the serviceable employment of borax in ceramic glazes. In the course of many experiments it has been found (1) that borax does not of itself form a satisfactory glaze, and (2) that *excess* of borax induces defects, such as crazing, blistering, injury to underglaze colours, injury to the stability of the glaze, thickening of the glaze to an unworkable jelly-like state, when the borax used is in the proportion by weight of double the total weight of all the other ingredients. When, on the contrary, the proportions were judiciously balanced in accordance with the dictates of experience, no such undesirable defects appeared; for example, in No. 2688 (p. 108), No. 2749 (p. 109), No. 2747 (p. 117) of *Researches on Leadless Glazes.*

In like manner, there are technical limits to the successful use of lead compounds in glazes and enamels. Cunynghame states that "Lead can be added so as to raise the specific gravity up to 5, and enormously to increase the refractive power; but flint glass so dense as this is very difficult to make, because the lead is apt to separate and cause devitrification. . . . . There is, however, a danger that it may be reduced to a metallic state during the melting. A very slight quantity of free carbon present in the mixture would effect this, for a quantity of carbon can reduce to a metallic state more than thirty times its weight of lead." (*Art Enamelling upon Metals*, p. 156, Constable.)

Influence of Silica in Glazes.—Alone, and at normal temperature, the affinities of silica are dormant, and when perfectly pure it will even endure the greatest heat of a potter's kiln without apparent chemical change, yielding only to the heat of the oxyhydrogen flame.

It is, however, not alone, but in intimate association with other ingredients, that silica takes its place in glazes. Under these more congenial conditions, when subjected to heat, silica develops powerful affinities, displacing nearly every other acid except boric, and uniting more or less strongly with the bases present, the readiness with which combination takes place differing according to the nature of the bases and the relative proportions of the compound.

When fused with carbonate of soda, a silicate of soda is formed; with lime, a silicate of lime; and so on. But while a mixture of equal parts by weight of silica and lime will at a certain temperature melt, a mixture of 80 per cent. lime with 20 per cent. silica only yielded a yellowish-white loose powder, and a mixture of 20 per cent. lime and 80 per cent. silica merely formed a somewhat brittle mass.

These intricate affinities bring about very peculiar phenomena, as, for example, felspar containing 64 per cent. silica melts at about 1200° C., while

kaolin containing only 48 per cent. silica is highly refractory up to about 1800° C.

Investigations into the nature and properties of Portland cement have shown, incidentally, that the reaction temperatures of mixtures of lime carbonate and free silica alter in proportion to the fineness of the silica. When the silica in such a mixture is in a very fine condition, reaction commences at about 950° C.; whereas, with silica coarser than the size between 120–150-mesh sieve, it is inert at temperatures up to 1350° C. (*Trans. A.C.S.*, vol. v. p. 94.)

Again, in connection with the sand-lime brick industry, it has been shown that certain reactions may take place, under steam pressure of 150 lbs. to the square inch, even at 185° C.

Silica is also found to be itself capable of solution at high temperature and in certain associations. Mr. Ross C. Purdy, of Columbus, states that "Feldspar when fused, or in a liquid state, is capable of dissolving silica. A. Buenzli found, with the aid of the microscope, that at high temperatures feldspar will dissolve a quantity of silica, and that the amount of dissolved silica increased with the rise in temperature." (*Trans. A.C.S.*, vol. v. p. 142.)

Dr. Hofman, after a series of researches upon slag silicates, remarked:—"We now generally look at slags as solutions of one silicate in another; so if a slag is composed of one silicate dissolved in another, we obtain low-fusion temperatures; and when we get an excess of either acid or base, it does not so readily dissolve, and hence causes irregularities."

To the rule that, under the influence of heat, silica, when intimately mixed with other mineral substances, displaces nearly every other acid and fixes itself to the bases, there are notable exceptions, one of which is of interest in ceramics. For if boric acid is present in the mixture, it refuses to be elbowed out, and therefore the two acids remain in the mixture, forming what are known as boro-silicates.

But boric acid has a tendency to promote easy fusion, particularly in the presence of alkalis, and thus it often happens that the resulting boro-silicates are of a much more fusible character than the silicates themselves would have been. This reaction has been largely made use of in the ceramic industry since the introduction of borax about A.D. 1796, and is now practically an indispensable one to the trade.

In a combined form silica is an essential component of all durable glasses and ceramic glazes with which we are acquainted; it is found in glasses of the Egyptians, Phœnicians, Greeks, Romans, Venetians, and Austrians. Of contemporary glasses, it forms 51 per cent. of flint glass, 70 per cent. crown glass, and 73 per cent. of Bohemian hard combustion-tube glass. Of glazes and glaze frits, it forms 54 per cent. of Dr. Thorpe's insoluble glaze frit, 57 per cent. of Minton's leadless glaze, 50 per cent. of Owen's leadless glaze, 52·9

per cent. of Boch Frères' glaze frit, 57 per cent. of Shaw & Co.'s glaze, 61 per cent. of Holdcroft's glaze. (See Government Report.)

But to lay down rules as to the precise proportion of silica most suitable for each purpose in ceramics is not an easy task. Indeed, it appears that glazes are not, correctly speaking, definite chemical compounds, but often are of the nature of solutions of one silicate or compound in another. And if one may judge by the motley variety of compositions at present in actual use in Great Britain as ceramic glazes, the theory of chemical equivalents as applied to glazes, to say the least, must permit of considerable elasticity.

Fownes writes:—"Glass is a mixture of various insoluble silicates with excess of silica, altogether destitute of crystalline structure" (p. 389).

Cunynghame, in greater detail, writes:—"It is sometimes recommended that the proportions of silica, oxide of lead, and alkali in glass should bear some definite ratio to the chemical equivalents of those materials, with a view to making the resulting glass rather into a chemical combination than a mere alloy; but it has been pointed out that the mixtures or alloys of metals and other substances may be made without any regard to combining proportions, and indeed the adoption of these proportions might rather have the effect of making the glass crystalline, that is to say, of its becoming devitrified, than of assuming that perfectly amorphous condition which is so valuable." (*Art Enamelling upon Metal*, p. 155.)

On the other hand, Dr. Seger, Dr. Thorpe, K. Langenbeck, and Professor Binns appear to favour the idea of compounding glazes, according to definite chemical formulæ.

Dr. Seger assumed that the composition of normal glass is always

$$\left.\begin{matrix} 0{\cdot}5K_2O(Na_2O) \\ 0{\cdot}5CaO \end{matrix}\right\} 2{\cdot}5\text{–}3{\cdot}0SiO_2,$$

and in his classical researches for leadless glazes for white earthenware he based his experiments largely on this formula as a starting-point. Yet he found it desirable to add kaolin mechanically to all his frits, and only by that means attained such success as he did. Possibly a less close adhesion to the theory of chemical equivalents would have helped rather than hindered his purpose; for if Fownes and Cunynghame are correct, then chemical theories will not of themselves indicate the best glazes, but much must be learned by purely empirical trials and tests. Indeed, Professor Binns, in another place, felt constrained to say that "In addition to the bases and acids, it has been found necessary to introduce certain components which occupy a neutral position." (*Ceramic Technology*, p. 72.)

Mr. W. Jackson, A.R.C.S., seems to have recognized and acknowledged the point we are now contending for in his recent work on *Ceramic Calculations*, for he writes:—"In dealing with pottery bodies and glazes, it is advisable, in many cases, to express their composition as a chemical

formula, as well as in the form of a percentage. When thus expressed, the relationship existing between their different parts, *e.g.*, acids and bases, can be more readily perceived. . . . . It must, however, always be borne in mind that the full meaning attached to such a formula as H_2SO_4, for sulphuric acid, cannot be read into a glaze or body formula. There is, in the latter cases, no intention to convey the idea that the formulæ represent well-defined chemical compounds. The only reason the formulæ are used is that they show the proportions existing between the molecular quantities of the several oxides present in these heterogeneous mixtures." (*Ceramic Calculations*, p. 24, Longmans.)

The licence with which scientific ceramists, as a last resource, recommend the addition of a little of this or of that ingredient to adapt glazes to different temperatures or different bodies, is also evidence against the theory that glazes are strictly chemical compounds. For instance, Professor Binns, in *Ceramic Technology*, when referring to crazing and moulting, writes:—"If a small amount of silica . . . . be added to a glaze, it will serve as an antidote to crazing, but always with the effect of making the glaze harder." (*Cer. Tech.*, pp. 74, 75.)

If, therefore, a scientific ceramist may add "a small amount" of this or that, for this or that purpose, so, surely, may the practical potter; but what then of chemical equivalence?

Crazing and peeling, or moulting (or chipping), of glazes exhibit stranger manifestations than have been fully discussed in the observations by Professor Binns as expressed in *Ceramic Technology*, and therefore demand more profound explanations and remedies; and it is more than doubtful whether relative chemical composition is the chief arbiter in these matters.

Glassy silicates, when formed, exhibit great differences of solubility in water. To determine this in a series of glasses experimentally made by known formulæ, Professor Orton took one gram of each glass, previously powdered and put through a 100-mesh screen, and treated these separately, each with 50 c.c. of distilled water, on a water-bath for ten hours, with frequent stirring. Finally the liquids were filtered and the filters washed, and the weight of solid residue determined, with results shown below:—

No. of Glass.	Molecular Formula.	Per cent. dissolved in Water.
1–Y, ...	1·00Na_2O, 0·00CaO, 2·00SiO_2	100·00
1–Z, ...	0·85 ,, 0·15 ,, 2·00 ,,	24·56
2–A, ...	0·70 ,, 0·30 ,, 2·00 ,,	9·88
2–B, ...	0·60 ,, 0·40 ,, 2·00 ,,	4·43
2–C, ...	0·50 ,, 0·50 ,, 2·00 ,,	4·21
2–D, ...	0·75 ,, 0·25 ,, 2·00 ,,	4·15
2–E, ...	0·00 ,, 1·00 ,, 2·00 ,,	Not determined.

All these phenomena go to prove the diversity of the influence of silica in glazes, and the legion of considerations involved one way or other, and the vastness of the task of those who would theorize on the subject with the object of building up a science of ceramics.

Influence of Alumina in Glazes.—In common with oxides of iron, manganese, chromium, tin, and certain other metals, alumina possesses the quality of reacting in a compound sometimes as an acid and sometimes as a base; at least, chemical parlance gives that impression, for we speak of borate of alumina and silicate of alumina, and, on the other hand, of potassium aluminate and sodium aluminate.

Knapp asserted that in a glass "Alumina, of all the ingredients, increases the difficulty of fusion most, so that when present in a certain very slight excess the glass is enabled to resist the heat of the furnace."

Rutley remarked that "Aluminium forms but one oxide, which alone is infusible except before the oxyhydrogen blow-pipe."

We all know that kaolin containing 38 per cent. alumina, as silicate of alumina, is highly refractory; while orthoclase felspar containing 18 per cent. alumina, as a double silicate, melts at porcelain-kiln temperatures. And that fireclays are generally supposed to be refractory in proportion to the ratio of the alumina with the iron, alkaline earths, and alkalis present. These things mark out alumina as a refractory substance, and perhaps have denied it the attention it deserved as a glaze ingredient.

But more recent investigations have emphasized other qualities in alumina. R. C. Purdy reminds us of the findings of Dana, viz., that labradorite, one of the most aluminous of the feldspars, is also the most fusible. (*Trans. A.C.S.*, vol. v. p. 140.) He tells also, among other deductions from the tables of Seger's trials, "that it appears distinctly that neither the glazes lowest in alumina are really the most fusible ones, nor those with a higher content of alkali; but that for low fusibility there must evidently be a definite proportion between the alumina and fluxes." (*Trans. A.C.S.*, vol. v. p. 139.)

Barringer has shown that when alumina was eliminated from a salt-glazing body, the salt had no action on the pieces whatever. (*Trans. A.C.S.*, vol. iv., and *British Clayworker*, June 1903, p. 21.)

Professor Orton has demonstrated that a glass of the composition $\left.\begin{matrix} \cdot 5Na_2O \\ \cdot 5CaO \end{matrix}\right\} 0{\cdot}20Al_2O_3, 0{\cdot}8SiO_2$ was more fusible at Cone 8 than a glass $\left.\begin{matrix} \cdot 5Na_2O \\ \cdot 5CaO \end{matrix}\right\}$ $0{\cdot}5SiO_2$. (*British Clayworker*, July 1903, p. xxxiii.) Following this up, Barringer has shown that the lime may with advantage be displaced by Al_2O_3 up to the formula $\left.\begin{matrix} \cdot 5NaO \\ \cdot 1CaO \end{matrix}\right\} \cdot 133Al_2O_3, 0{\cdot}50SiO_2$—and indeed that the lime may be even completely displaced by alumina and yet a good glass obtained. (*Ibid.*)

Again, in endeavouring to thrash out the matter of the development of a

matt glaze, Professor Binns paid great attention to the influence of alumina, and drew the conclusion that "Alumina has a very large part to play in the production of matt glazes. . . . . It may be said to have the most important part of any glaze constituent." (*Trans. A.C.S.*, vol. v. p. 56.)

But lest this be understood as finally attaching an invariably refractory or dimming influence to alumina, Professor Orton, in the course of the discussion, observed that "Alumina does not always seem to assist in the production of mattness; but, on the other hand, may frequently powerfully assist in the production of glassiness. That principle was first stated by Mr. Langenbeck in his book when he called attention to the difference between glazes and glasses, *i.e.*, that in the glass the ware is cooled so suddenly that no chance for devitrification is given, and alumina is therefore not needed, and is, in fact, either low in amount or altogether absent; while in the glaze it is only by the use of alumina that we can prevent devitrification during the long cooling in the kiln. . . . . One of my glasses produced last year showed this point beautifully. It was a series of glasses in which I had been persistently reducing the silica contents. I started with $RO, 2{\cdot}5SiO_2$, and reduced the SiO_2, one-half equivalent at a time to a very basic glass, $RO, 0{\cdot}5SiO_2$. The basic mixtures were not like glasses; they were more like stones. I then tried adding alumina to one of these same stony basic slags. The first addition reduced the stony condition greatly; the second produced a beautiful clear glass. In the third addition the glass had gone beyond the point of maximum fusibility, and particles of white unfused matter were floating around in the clear matrix of the glass. Further additions of alumina made it stony again. There seemed to be a point where alumina made a stony basic slag in a perfect glass, but, also, it seemed equally clear that too much alumina converted the glass back to the stony condition again." (*Trans. A.C.S.*, vol. v. p. 58.)

Seger observed the dimming of glazes in the course of his classical series of leadless-glaze experiments; but, according to Bleininger's translation, he found in several cases that the cause of the dimming was a too low alumina content, and that the trouble disappeared on increasing the alumina.

In the case of lead glazes, Seger believed that alumina had a tendency to make glasses dim and milky, and that it was considered risky to raise the alumina contents too high; but he expressed the opinion that this assumption is entirely incorrect for the alkali-lime glasses, which require a high content of alumina in order to produce transparent glasses at all on slow cooling; without it, they become opaque.

He writes (according to Bleininger's translation):—"Glasses free from alumina, of the composition

$$\left.\begin{matrix} 0{\cdot}3K_2O \\ 0{\cdot}7CaO \end{matrix}\right\} 2{\cdot}5SiO_2,\ 0{\cdot}5B_2O_3,$$

were compounded and fused . . . . but produced perfectly milky masses entirely unsuitable as glaze frits." And, after numerous trials, he tells us that "Further attempts to produce glazes with frits free from alumina, or low in it, were not made, and only frits with a high content of alumina were employed, because these proved more successful." And again:—"Glazes still higher in alumina . . . . were likewise satisfactory and suitable for technical purposes."

Of certain frits he writes:—"They became clear only when the addition of clay was considerable. . . . . In the last a distinct opalescence of the glass was shown. This disappeared entirely on increasing the alumina contents of the glaze still more by grinding 10 per cent. of Zettlitz kaolin together with the frit, and applying this mixture. . . . . The last two frits, however, produced perfectly transparent and shining glazes when their alumina content was increased by an addition of 10 per cent. of Zettlitz kaolin on grinding."

Thus Seger was convinced that alumina was far from being merely a refractory agent in glazes, and that in reality it exercises most important functions of a totally different character.

Professor Orton has ventured to assert that "It is only by the use of alumina that we can prevent devitrification during the long cooling in the kiln." (*Trans. A.C.S.*, vol. v. p. 58.)

And the writer can add his own experience, which is that, in respect of removing or preventing opalinity from certain lead-free glazes, alumina is more effective than china-clay at the low temperatures employed for majolica glaze-tile kilns, and that the free alumina usually answers this purpose best when mechanically mixed with the frit by grinding. (See *Researches on Leadless Glazes*, pp. 92, 93.)

Whatever may have been the experience of other practical experimenters in this field of research, the writer can say, for his own part, that ALUMINA IN THE FREE STATE has certainly been a most powerful factor in the most successful of his trials of glazes maturing at low temperatures.

With harder-fired earthenware glazes a similar mechanical addition of china-clay usually effects a like object; but china-clay is not always efficacious in easily fusible coloured glazes; free alumina is much more effective. Of course, differences in the mode of firing and cooling, and different proportioning of the frits, all exert influence in the matter of opalinity; but in many cases, upon finding the suitable frit and adding the necessary quantity of free alumina, opalinity usually disappeared, and it was sometimes remarkable what a large quantity of free Al_2O_3 could be borne.

Excess of alumina does not, like excess of lead or copper, form a metallic film—it is not so easily reducible; but the excess shows itself either in a dulling of the surface or interior effect, and ends, if great excess is present, in a very harsh, dry surface.

The experience of other research ceramists is also very interesting. For instance, Langenbeck has the following pregnant sentences :—"The practical experience of the potter teaches him that he needs as a glaze a body resembling in hardness, color, and refracting power ordinary flint glass; but that ground flint glass, painted on his ware and exposed to the kiln, will not, under any circumstance, give him a glaze having the qualities the glass before in itself had, but a puckered, devitrified mass, barely sintered together. . . . . The potter has found empirically that no glaze can be perfect without the addition, in certain proportion, of either clay, feldspar, or Cornwall stone; and the chemist will readily recognize that the new element introduced by these materials is merely alumina, and that it is this and other chemically similar elements which keep the glaze from devitrification in the protracted 'glost fire' of the potter's oven." (*Chemistry of Pottery*, pp. 50 and 51.) Langenbeck subsequently describes certain practical trials made with bottle-glass of the soda-lime type. When "finely ground and applied to a burnt shard of clay, it was scarcely possible to get with it a bright transparent glaze in the experimental muffle." Then an experiment was made with a mixture consisting of 52·71 flint glass, 55·75 litharge, and 38·4 flint, mixed with water and painted on a potsherd. This at first flowed to a brilliant glaze at a temperature above that of the melting-point of an alloy 50 per cent. silver and 50 per cent. gold; but in a potter's glost kiln, when subjected to "thirty hours' firing and two days' cooling, the glaze was puckered and dull."

Then alumina was tried. Langenbeck explains it thus:—"The introduction of two-tenths equivalent of alumina, in the form of china-clay, with allowance for the silica necessarily introduced with it, corrected it for these conditions, so that the glass, composed of flint glass 52·71 parts, litharge 55·75 parts, china-clay 25·9 parts, and flint 26·4 parts, answered on a shard of the proper coefficient of expansion, and came brilliant and clear from the long fire." (*Chemistry of Pottery*, p. 53.)

Binns, in *Ceramic Technology*, is equally emphatic, if not so explicit, in his assertion that it is impossible to construct a satisfactory glaze without alumina.

Hence, silica is essential, alumina is essential, but lead oxide is not essential in ceramic glazes; indeed, in the absence of alumina it breaks down altogether as a glaze ingredient.

Alumina possesses two other important qualities which exhibit themselves when it is used in glazes, namely, a toughening and a bleaching power. A comparison of stoneware with glassware will be sufficient proof of the toughening influence of alumina. And the whiter colour of certain china glazes containing free alumina is equally demonstrable; that is to say, glazes to which free alumina has been mechanically added by grinding it with the

frit prior to application of the glaze are perceptibly whiter than when such addition is not made.

Influence of Lime in Glazes.—Lime is the only known oxide of calcium; but it has lately been assumed to exist sometimes in an amorphous state, and at other times in a vitrified crystalline condition. These, though not distinguished analytically, are different physically. (*Trans. A.C.S.*, vol. v. p. 83.)

Lime is of itself a very infusible substance; so much so, as to be used as an incandescent medium in oxyhydrogen lamps. It is, nevertheless, one of the five principal basic oxides used by metallurgists, glassmakers, and ceramists for fluxing silica and silicates, and of these five fluxes it has the advantage of being cheapest.

Seger asserts (Bleininger's trans.) that "Lime glasses are transparent only when they contain also alkalies as fluxes," and states that the composition of a normal glass is always assumed to be as follows:—

$$\left.\begin{matrix} 0{\cdot}5K_2O \\ 0{\cdot}5CaO \end{matrix}\right\} 2{\cdot}5\text{–}3SiO_2, \quad \text{or} \quad \left.\begin{matrix} 0{\cdot}5Na_2O \\ 0{\cdot}5CaO \end{matrix}\right\} 2{\cdot}5\text{–}3SiO_2.$$

Lime forms an almost essential or, at least, highly desirable ingredient in many glasses, partly to impart insolubility, hardness, and brightness, and partly to enable the glasses to bear long, slow cooling certain glasses are subjected to, such as those composed of lime, potash, and silica, used for the manufacture of telescope objectives.

In stoneware glazes, brick or fireclay ware glazes, and in hard-porcelain glazes, lime is frequently introduced to assist in fluxing the clays and felspars associated with it as a glaze.

Its behaviour under these conditions has been very closely studied by Mr. Ross C. Purdy, of Columbus, who read a paper, containing a record of his results, before the American Ceramic Society, entitled, "Further Studies on White Bristol Glazes." (*Trans. A.C.S.*, vol. v. p. 136.)

But it is with the softer, more easily fusible glazes we are concerned; and, as already noted in a preceding paragraph, Professor Orton has supplied a mass of most valuable information regarding, among other things, the behaviour of lime when compounded in easily fusible mixtures.

The writer's personal experience goes to show that, under the conditions and for the purposes we are considering, it is desirable that the lime should almost always be melted in a frit with the other ingredients, not added as a mechanical mixture, except when it is desired to influence the tints imparted to the glazes by iron oxide or cobalt oxide.

A comparison of results of several tests will demonstate this. (See *Researches on Leadless Glazes*, pp. 87 and 92.) These show an undesirable effect from the use of mechanically mixed lime in the glaze.

No. 2514.

2 dr. fritt No. 2132. ¼ ,, alumina. ¼ ,, zinc oxide.	At majolica-tile glost heat, yielded an excellent glaze with few bubbles, not crazed on white body.

No. 2571.

2 dr. fritt No. 2132. ¼ ,, whiting. ¼ ,, zinc oxide.	At majolica-tile glost heat, yielded a glaze that caused body foveations, and crazed on cream-tint body.

No. 2708.

1½ dr. F.L.G. fritt. ¼ ,, alumina.	At majolica-tile glost heat, yielded a clear glaze with a little floating scum.

No. 2713.

1½ dr. F.L.G. fritt. ¼ ,, whiting.	At majolica-tile glost heat, yielded a glaze mostly opaline. Starry surface, and crazed.

On the other hand, instances occur when the addition of lime effects marked improvement. (See p. 91, *Researches on Leadless Glazes.*)

No. 2682.

5 lbs. fritt No. 2662. 1 ,, ground pitchers. ¼ ,, china-clay.	All ware badly crazed and blistered ; destroys U.G. pink ; suits greens and neutral.

No. 2762.

1¼ dr. glaze No. 2682. ¼ ,, whiting.	Compared with 2682, fired at the same time, this is less crazey, much freer from bubbles, and altogether a vast improvement.

A mixture of borax and carbonate of lime in equal parts, melted on a tile, resulted in a fearfully crazed glaze ; but a mixture of boric acid, silica, and carbonate of lime, similarly tested, resulted in a glaze not crazed.

The presence of lime is generally assumed to be beneficial in glazes used upon wares painted or printed with U.G. pink colour ; it seems also desirable for the choicest developments of cobalt blues. Yet good glazes can be made without either lime or lead compounds.

Comparing the behaviour of CaO, MgO, BaO, ZnO in easily fusible glasses, Professor Orton has said :—" It had been noticed that in all the cones . . . . in which MgO, BaO, ZnO partly or wholly replaced CaO . . . . a tendency was evinced to swell up in fusing, and instead of proceeding at once to clean-cut fusion, to form a puffy mass in which no definite end reaction could be gotten." (*Trans. A.C.S.*, vol. v. p. 328.)

So that, not to mention the advantage of cheapness, lime evidently is very often a most useful ingredient in glazes, in a purely technical sense.

It has been proved that soda-lime glass of the usual composition is unsatisfactory as a potter's flux (*Trans. A.C.S.*, vol. v. p. 310, and *Chemistry of Pottery*, p. 50) ; but the behaviour of lime in the presence of boric acid and alumina redeems its character as an ingredient of ceramic glazes. Indeed,

it is upon lime in association with alumina that we rely for hardness and insolubility of lead-free glazes, and for much of the brightness.

Lime must be credited with two other beneficial effects in glazes. Firstly, it is admitted to yield glasses of less brittle nature than lead glasses, hence it is reasonable to infer similar influence on the part of lime in glazes. No doubt the alumina performs this function so well as to mask the influence of lime; still, it would be unfair to pass over such a desirable quality without comment. Secondly, lime has been observed to cause a frit to adhere more tenaciously to pitcher than do the alkalies; this also should be noted. Langenbeck's experience with feldspars coincides with this, for he states that a potash feldspar melted on a pottery body cracks off one upon which a siliceous soda-lime feldspar remains immovably fixed. (*Chemistry of Pottery*, p. 110.)

When the presence of carbonic acid gas is undesirable, the lime should be introduced either as free lime or as silicate or borate of lime.

Influence of Potash in Glazes.—Prior to Leblanc's discovery, in A.D. 1792, of a cheap method of making carbonate of soda from common salt, and prior to the introduction of borax to the ceramic art, the compounds of potash figured much more prominently in recipes for glazes and enamels than they do at the present day. Even after the valuable properties of borax had been recognized, while it was expensive (3s. to 4s. per lb.), we find directions in old potters' recipe-books for the preparation of a substitute for borax of the nature of crude potash sulphate. Otherwise the compounds of potash then most generally used were the ordinary *pearlash* and *nitre* of commerce.

If lead oxide is indispensable, as some suppose, why were not our ancestors content with it? Why did they use pearlash and nitre? Probable reasons may be those that influence glassmakers, viz., (1) potash produces whiter, more colourless glass than lead; (2) the glass so produced is less liable to metallic reduction.

With regard to the first point, we find potash in all the best glasses. Fownes gives the composition of three thus:—

Hard Bohemian for Tubes.		Bohemian Plate-Glass (excellent).		English Flint Glass.	
Silica,	72·80	Silica,	60·0	Silica,	51·93
Potash,	16·80	Potash,	25·0	Potash,	13·77
Lime,	9·68	Lime,	12·5	Lead oxide,	33·28
Magnesia,	0·40				
Manganese, etc.,	0·32				
	100·00		97·5		98·98

and adds that "Potash gives a better glass than soda." (Fownes' *Chemistry*, 10th edition, pp. 390, 391.)

Then as to the second point, Cunynghame has written :—" There is, however, an important use to which the nitrates of potash and soda can be put, and which renders them indispensable ; it is due to their great oxygenating power. . . . . Oxide of lead is especially liable to this reduction, which causes the mass of enamel to become of a dirty black colour. Throughout the whole operation of melting enamels it is therefore necessary to keep the mass of melted matter well oxidized, and for this purpose no ingredient is so valuable as nitrate of potash." (*Art-Enamelling upon Metals*, pp. 153 and 154.)

Hence, when lead oxide is not employed, there is very much less need for the use of nitre.

Results of numerous experiments, both with frits and glazes, point to the conclusion that potash has greater tendency to induce opalinity than has soda ; thus on pp. 92 and 93, *Researches on Leadless Glazes*, we have :—

No 2709.
$1\frac{1}{2}$ dr. F.L.G. fritt.
$\frac{1}{4}$,, soda-ash.
} At majolica-tile glost heat. Clear glaze. Crazed.

No. 2710.
$1\frac{1}{2}$ dr. F.L.G. fritt.
$\frac{1}{4}$,, nitre.
} At majolica-tile glost heat. Opaline edges. Crazed.

No. 2770.
$1\frac{1}{2}$ dr. F.L.G. fritt.
$\frac{1}{4}$,, china-clay.
} At majolica-tile glost heat. Perfectly clear glaze. Not crazed.

No. 2772.
$\frac{3}{4}$ dr. F.L.G. fritt.
$\frac{3}{4}$,, 2660 fritt.
} At majolica-tile glost heat. Perfectly clear, without a bubble. Not crazed. Slight opalinity at corners only.

No. 2773
$\frac{3}{4}$ dr. F.L.G. fritt.
$\frac{3}{4}$,, 2662 fritt.
} At majolica-tile glost heat. Wonderfully clear, practically no bubbles. No trace of opalinity. Not crazed.

No. 2774.
$\frac{3}{4}$ dr. F.L.G. fritt.
$\frac{3}{4}$,, 2132 fritt.
} At majolica-tile glost heat. Perfectly clear, not a bubble. Not crazed.

No. 2775.
$\frac{1}{2}$ dr. F.L.G. fritt.
$\frac{1}{2}$,, 2660 fritt.
$\frac{1}{8}$,, nitre.
} At majolica-tile glost heat. Partly opaline. Crazed.

Several other experiments could be cited pointing to the same conclusion, viz., that potash in the presence of lime in a frit is liable to induce opaline effects.

Respecting the combination of potash with silica, Muspratt has pointed out that if one part of silica and three parts of potash are fused together, the glass so formed will melt at a cherry-red heat, and will be soluble in cold water ; whereas when six equivalents of silica and one equivalent of potash are fused together, the glass is only fusible by the heat of a very powerful forge.

It is well known that a combination of soda and potash with silica pro-

duces more fusible compounds than either alone. This is turned to practical use not only in the chemical laboratory but also by ceramists; for instance, at Rörstrands a mixture of two different feldspars, one a soda feldspar and the other a potash feldspar, has been used with the object of securing more easy fusion. (See Government Report.)

The comparative influence of potash and soda in an enamel has been expressed by Cunynghame thus:—"Potash is best when it is desired to obtain whiteness and brilliancy, but when a glass is required which shall be easily fusible, elastic, and which shall possess the valuable property of remaining ductile for some time after it is heated red-hot, or in other words, of being malleable at a red heat, soda is employed. (*Art-Enamelling upon Metals*, p. 152.)

With these ingredients, as with others, the all-important question of relative proportion must never be overlooked. Excess of alkali in a glaze tends to induce facility of fusion, but at the same time renders the compositions more soluble, more efflorescent, and more easily decomposed or decayed. On the other hand, deficiency of alkali causes sluggishness in melting, vesicularity, and want of transparency. The exact proportions most desirable for each purpose can only be discovered by experiment.

For better or for worse, however, artificially prepared salts of potash have now been largely displaced by borax in many ceramic formulæ.

Influence of Soda in Glazes.—The consideration of this ingredient introduces a more or less exciting topic from the manufacturer's point of view, because, next to lime, soda is the cheapest of all the fluxing substances used in the ceramic art. The monetary value of lime weight for weight is less, but lime is not so powerfully fluxing as soda in relation to silica; and for ceramic purposes, in the easily fusible glazes, lime is always assisted by either soda, potash, lead, or boracic acid.

Of these fluxing substances it is interesting to compare the current prices. They are approximately as under:—

Borax, refined,	£14	0	0	per ton.
Boracic acid, refined,	23	0	0	,,
Carbonate of lead,	24	0	0	,,
Pearlash,	24	0	0	,,
Soda-ash,	4	0	0	,,
Lime carbonate,	1	10	0	,,

These figures, however, would be misleading without calculating at the same time the yield of each when fused with silica into a frit or enamel; so we must reckon it thus:—

Borax, refined,	$37\frac{3}{4}$	cwts. =	1 ton fused;	costs	£26	8	0	per ton when fused, neglecting cost of fusing.
Boracic acid,	$36\frac{1}{4}$	,, =	1 ,,	,,	41	19	6	
Lead carbonate,	$23\frac{3}{4}$	,, =	1 ,,	,,	28	10	0	
Pearlash,	30	,, =	1 ,,	,,	36	0	0	
Soda-ash,	$34\frac{1}{2}$	,, =	1 ,,	,,	6	18	0	
Whitening,	$37\frac{3}{4}$	,, =	1 ,,	,,	2	16	7	

That is to say, soda and lime together would cost weight for weight in a frit about one-fifth of any of the other fluxes.

The question then arises—can a satisfactory glaze be produced by associating silica with these two cheap fluxes, soda and lime? Now, we know that a great quantity of good glass is so produced, but Langenbeck says glass does not answer for a glaze. What, then, converts a glass into a glaze? In substance and in a word Langenbeck replies, Alumina. (See *Chemistry of Pottery*, pp. 50–53, Chemical Publishing Co., Easton (Pa.), U.S.A.)

Pioneering potters' chemists would find here a useful field of research to discover by repeated experiment what proportions of silica, lime, soda, and alumina yield the most easily fusible glaze. Seeking first what compound of silica, lime, and soda yields the most perfect and most permanent glass, and then by displacing a small proportion of the lime by alumina, judiciously introduced after fritting, form it into a glaze. When this has been repeatedly done and carefully got to its most satisfactory proportions, bring the fusibility to the required temperature by replacing the least possible proportions of soda and silica in the frit by borax.

A very great step in this direction has been taken by Professor Orton, for he has shown that in soda-lime glasses the maximum soda content which such a glass may have, without sacrificing its stability under the attacks of solvents, may be represented by the formula :—

$$\left.\begin{array}{l} 0{\cdot}60Na_2O \\ 0{\cdot}40CaO \end{array}\right\} 2{\cdot}00SiO_2.$$

(*Trans. Am. Cer. Soc.*, vol. v. p. 319.)

An attempt to produce a cheap glaze was also made by the author in 1898. (See *Researches on Leadless Glazes*, p. 97.) Two frits were compounded as follows :—

No. 2755.

$$\left.\begin{array}{lll} 4 & \text{lbs.} & \text{Cornish stone.} \\ 2\frac{3}{4} & ,, & \text{calcined flint.} \\ 2\frac{1}{4} & ,, & \text{refined borax.} \\ 2 & ,, & \text{soda-ash.} \end{array}\right\} \text{Fritted.}$$

No. 2758.

$$\left.\begin{array}{lll} 9 & \text{lbs.} & \text{Cornish china-stone.} \\ 2 & ,, & \text{soda-ash.} \end{array}\right\} \text{Fritted.}$$

From these a trial glaze was made up thus:—

No. 2827.

$$\left.\begin{array}{lll} 1\frac{3}{4} & \text{lbs.} & \text{No. 2755 frit} \\ 1\frac{1}{4} & ,, & \text{No. 2758 ,,} \\ 2 & ,, & \text{Cornish stone} \\ 1 & ,, & \text{felspar} \\ \frac{1}{2} & ,, & \text{china-clay} \end{array}\right\} \text{ground together.}$$

This yielded a glaze rather too hard for earthenware, but otherwise promising; it suited U.G. matt-blue and U.G. bronze-green, but injured U.G. pink.

The cost at that time was calculated to be 5s. 6d. per cwt., unground. This may be 8s. 6d. per cwt. ground, but when it is considered that the glaze weight for weight would dip much more ware than ordinary lead glaze, the possibilities show that these lines of research deserve more attention.

What appears to be needed is the addition of a little lime in one of the frits, say in No. 2758, or perhaps in both.

If used in excess in glasses or glazes, soda is disposed to induce efflorescence; and when sulphurous gases have access to the melting mixtures under certain conditions sulphate of soda may form, which may, when cold, show as semi-opaque beads, which can be picked off, leaving little pits. (*Chemistry of Pottery*, p. 55.)

It is well, therefore, to take measures for excluding sulphurous gases as much as possible from frits containing soda salts during fusion, and avoid using excessive proportions of soda.

Preparation of Frits and Fluxes.—Leadless-glaze frits and enamel fluxes, such as are described in the following series of recipes, may be fused, or "run down," in different furnaces, according to the quantities required, and whether the compositions contain colourant oxides or not. Small quantities for experimental purposes may be melted in gas-fired crucible furnaces, or may be put in biscuit cups and passed through suitable potters' or tilemakers' kilns. It is often advised that such cups or bowls be washed inside with a thick lining of ground calcined flint, to assist the frit in parting from the pitcher when fusion has taken place; but personal experience has shown that by the use of such lining the product is very liable to injury by combination or admixture with the flint. For the success of the trial it is better to use rather thick biscuit cups or bowls without any flint washing or lining, and upon breaking out the finished frit to sacrifice any parts that have adhering pitcher; and even if a little pitcher does adhere, it is often less injurious to the composition than flint would be. The same principle applies to fritting in large crucibles; for when a composition has been very carefully proportioned and compounded for distinct purposes, it may be disastrous to have appreciable additions of flint, particularly of irregular and unknown quantity.

Coloured frits, and any colourless frits that may be required in only small quantities, say a few cwts., or less occasionally, even for manufacturing purposes, may be conveniently melted in crucible flux kilns. These may be provided either with movable or with fixed crucibles.

The former are perhaps preferable when many different kinds of frit or flux have to be fused, because in some large kilns of this kind as many as fifty crucibles, containing 10 to 20 lbs. weight each of flux composition, may be melting simultaneously. The drawing of a small flux kiln shown in fig. 264 will almost explain itself; it is suitable for about nine rather small crucibles.

A flux kiln may be worked as follows:—The crucibles may be washed with calcined ground flint slip or not, according to the choice of the operator; then they should be marked for subsequent identification, and filled two-thirds full of the mixed composition it is desired to melt. They are then placed on the flat hearth of the furnace or kiln, and the door closed and luted: firing is then commenced, and should be followed up until it is ascertained either by trials or observations that the frits are sufficiently fused.

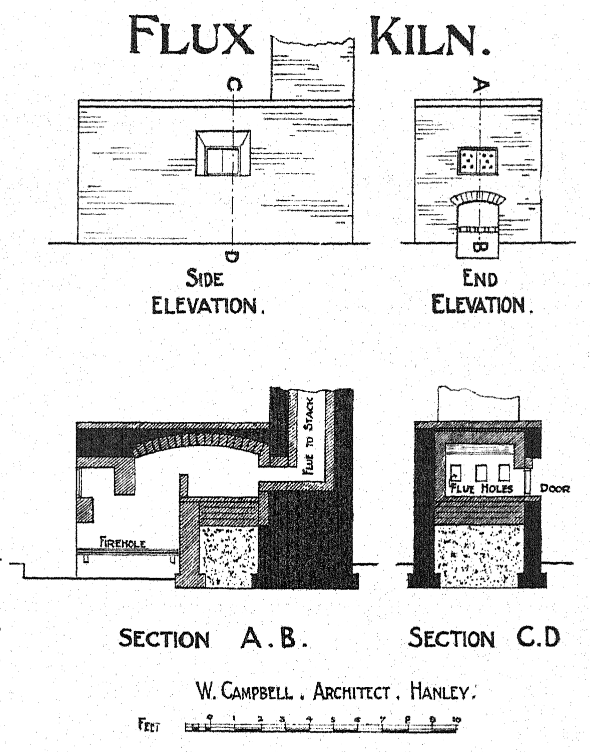


FIG. 264.—Flux kiln for nine movable crucibles.

When this stage is arrived at, the usual course is to quickly and momentarily open the door, and by suitable appliances take out the crucibles one by one, and pour the contents into a small tank or bucket of water; this operation disintegrates the glassy frit or flux into a coarsely granular condition. Then quickly refilling the crucibles, replace them in the kiln; when all have been thus discharged and refilled, the kiln firing may be proceeded with again as before.

Or another method may be adopted as follows:—The crucibles, when taken out of the kiln and while hot, may be cast into a tank of water bodily, and the shattered frit and broken crucible separated when cool.

Yet again, when the kiln is fired up and the frits all melted, the kiln may be allowed to cool, and then the crucibles removed and the frits or fluxes broken out separately. But slow cooling does not suit some frits, and great loss of heat and time and crucibles occurs by this last method.

When only a few kinds of frit or flux are to be fused, the crucibles may be stationary; apertures being made in the covering arch of the reverberatory furnace or kiln above each crucible, and also in the bottom of the furnace and of each crucible, so that they may be charged, discharged, and recharged again and again without removal. Underneath, in an accessible cavity under the

kiln, are arranged movable water-tanks, into which the fluxes may drop or flow when melted. By this arrangement the kiln need not be opened until some of the crucibles crack or collapse.

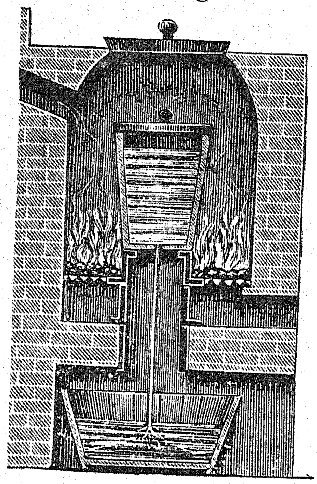


FIG. 265.—Single-crucible kiln. (See *Painting on Glass and Porcelain*, p. 133.)

By the courteous permission of Messrs. Scott, Greenwood, & Co., the writer is able to repeat here Hermann's illustration of both a single stationary crucible kiln arrangement and also a nine-crucible kiln.

In fig. 265 the outlet is closed by a close-fitting porcelain rod. The crucible may be replenished from time to time until nearly full of melted flux; then the plug is withdrawn, and the crucible empties itself into a tank of water below.

Langenbeck advises a hole in the crucibles of $\frac{3}{8}$-inch diameter, and a corresponding exit aperture in the supporting hearth underneath of $2\frac{1}{2}$ inches diameter. (*Chem. Pottery*, p. 132.)

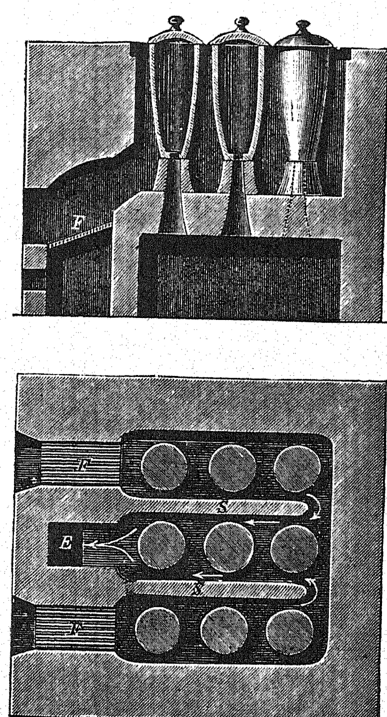


FIG. 266.—Nine-crucible flux kiln. (See *Painting on Glass and Porcelain*, p. 134, Scott, Greenwood, & Co.)

Large quantities, of over two tons and up to twenty or thirty tons of frits, largely used, are most economically melted in what are called "frit kilns." These may be of any charge capacity, from 1 cwt. up to 7 cwts. They are special reverberatory furnaces built of firebricks, with a concave melting hearth, having an aperture from its lowest point for discharging, and openings in the cover arch for charging and recharging. When working they must be kept going day and night continuously for several weeks.

The frit kiln may be worked as follows:—The charges or batches of mixed composition are first prepared. Each ingredient should be sieved separately through a suitable mesh sieve (say about $\frac{1}{4}$-inch holes), and the required proportions of each weighed out and the batch well mixed together either on a clean board or zinc-plated floor, or in a rotary mixer.

After again sieving, the mixed batch is placed in baskets or boxes containing about 28 lbs. each. When a charge is ready, the kiln fire having been started and got into a red-hot condition, and the outflow plugged securely with a flinted plug, the charge is cast in upon the concave hearth through the top apertures, which are then covered with fire-quarries, great care being exercised that the kilnmen do not tread upon the arch itself while heated, lest by accident it should collapse.

The kiln fires are "bated" and followed rapidly until a white heat is

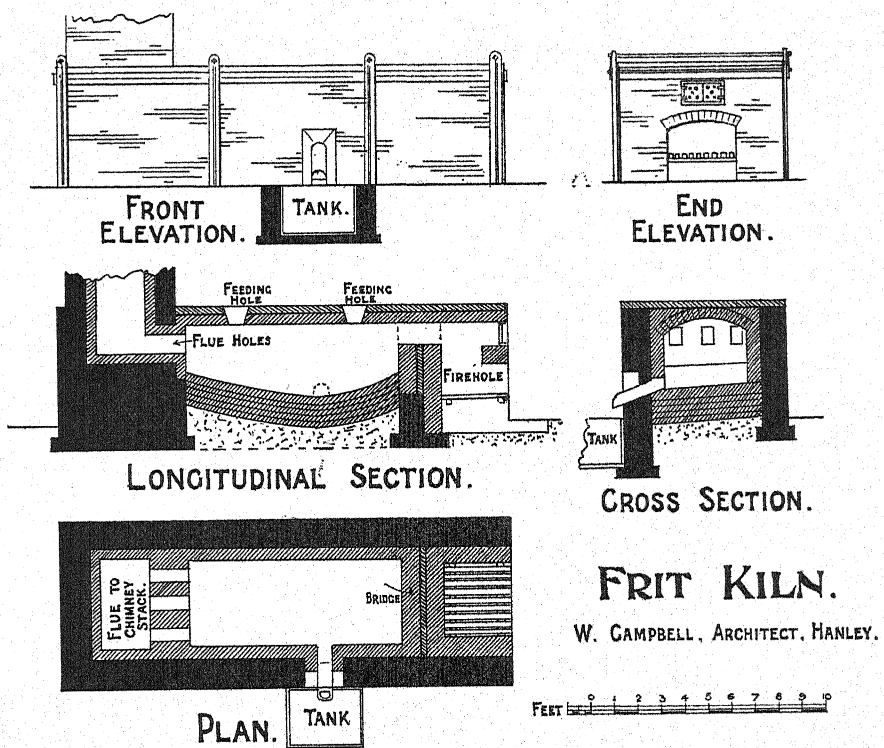


FIG. 267.—Glaze frit kiln.

attained. In about two and three-quarters or three and one-quarter hours' time the charge will usually have thoroughly melted, and be in a more or less fluid state, according to composition. This may be ascertained by looking in the apertures in the cover arch, and, if necessary, extracting a sample on an iron rod.

When the frit is quite ready for running off, water is allowed to flow into the cast-iron receiving tank, the outflow plug of the kiln cautiously withdrawn, and, if necessary, the outlet punched out clear of obstructing frit. The frit then

runs into the tank like red-hot sluggish syrup. Vast volumes of steam are caused by contact with the water, and the glassy frit is shivered into brittle fragments, convenient for further treatment. Care must be exercised, when running off, that the kilnmen are not burnt or scalded.

Immediately one charge is run off, the plug or stopper must be reflinted and replaced, and whilst the kiln is still quite hot another charge of composition must be cast in upon the hearth, through the top apertures.

This is repeated night and day, at interims of about three and a half hours, for several weeks, until the desired quantity has been melted.

The foregoing are all more or less intermittent processes. Probably some more continuous process is practicable, of the nature of rotary kilns, after the manner of the rotary clinker kilns used by Portland-cement makers, were it necessary to fuse very large quantities continuously.

The melting down in this manner of such infusible compounds as flint, Cornish stone, whitening, and kaolin arises apparently from the fact that such ingredients as soda-ash and borax, which form part of the compound, first melt in the kiln, thereby forming a fluid medium by which chemical decomposition and rearrangement of the other ingredients is promoted.

Seger has stated (Bleininger's translation) that "Mixing substances ever so intimately will not be sufficient to induce combination. Chemical processes rather presuppose an unrestricted motion of the molecules, and never take place between two solid substances; one of these, at least, must be in a liquid or gaseous state. Hence two solid substances will not produce chemical compounds unless a liquid is present that will dissolve one or both of them, and thus establish the proper contact." (Vol. i. p. 491.)

R. C. Purdy, of Columbus, Ohio, after making use of the above quotation, adds:—"This law of chemical reaction produced by the intermediation of a liquid or molten magma is not, in a ceramic mixture, *always* dependent *primarily* upon the fusibility of any one or more ingredients if taken alone. As has been shown in the case of clay and calcium carbonate, the reaction is facilitated or hastened by the chemical activity of the dehydrated clay. . . . . If the carbonate of calcium has reacted on the clay at 800° . . . . and the felspar has been reacted on at 900° and free quartz at 925°, it is plain to see that there is considerable silica in such a condition as to combine readily, forming silicates of the various bases present." (*Trans. A.C.S.*, vol. v. p. 142.)

These remarks were originally used in connection with stoneware glazes. In our own case the introduction of considerable amounts of borax very materially affects the temperature needed to bring the various ingredients into touch with one another. Whether this enables the whole of the reactions to be completed satisfactorily below the temperature at which fine silica and calcium oxide mutually react is, of course, doubtful.

Some curious things happen sometimes in the way of frits, and in practice, as in experiment, it is well to know a little of the experiences of others. For example, Mr. Owen Carter, in relating his story of their preparation of a crimson glaze, tells how, after numerous trials, they at last settled down to a given formula, preparing it in small charges at a time by fritting the composition in flinted saggers in front of the enamel kilns at 09. By and by the demand for this particular colour increased, and this method of calcining in saggers in the fronts of enamel kilns was found to be inadequate to the supply. Accordingly, fritting was arranged to be carried out in the crucible kiln, the crucibles being fed at the top, and the molten frit running out into water through a hole in the bottom of the crucible. To his horror, when walking round the works a day or so afterwards, he found the crucible kiln in full swing, but instead of a crimson, a bright grass-green frit was being yielded, which he was told was *sang-de-bœuf*. The fritting was stopped at once, some of the frit ground, and trials got in the kiln with least possible delay. It was expected the trials would come out a bright green like the tint of the frit, but to Mr. Carter's surprise and delight they were, if anything, a brighter and better red than tiles dipped from frit calcined in saggers. (*Trans. A.C.S.*, vol. v. p. 245.)

Preparation of Glazes.—The glaze frits having been prepared, these have to be finely ground, so that they may be readily suspended in water for dipping or glazing by immersion, and other customary modes of glaze application.

For some purposes a frit alone, or a compound of several frits only, may compose the glaze; in other cases unfritted or "raw" materials may be associated with the frit. In the former case grinding by wet methods is rendered rather difficult, and small quantities of common salt, or of ammonia carbonate, may have to be added to facilitate the wet-grinding. When such additions are undesirable, the frit may be ground dry in what is called an Alsing cylinder or ball-mill, and afterwards mixed with the necessary quantity of water.

For wet-grinding several kinds of mills are employed, according to circumstances and individual preference. Small quantities, such as 10 to 30 lbs., can be conveniently ground upon the old style of potter's colour-mill (fig. 268), which consists of an arrangement of a solid block of granite about 24 inches by 24 inches by 12 inches for a grinding base, upon which a cylinder of wood or vitreous pitcher is fixed, within which a granite muller is caused to revolve upon the granite base. Such mills are often erected in rows together, and are set in plaster bounded by or cased around with wood work or ironwork, the mechanical power being supplied by an overhead horizontal shaft. In the United States ball-mills are also used for wet-grinding, and when small quantities are needed colour-mills of this kind, such as fig. 270, may be used. The Crossley Manufacturing Co. also make

porcelain-jar mills of this kind in ranges or groups, with jars measuring inside $8\frac{1}{2}$ by $7\frac{1}{2}$, having a capacity of $1\frac{1}{2}$ gallons each, and to run at a speed of about 60 revolutions.

For very small quantities the "Little Trojan" mill (fig. 271), made by the Abbé Engineering Co., of New York City, seems to be a useful size. It is

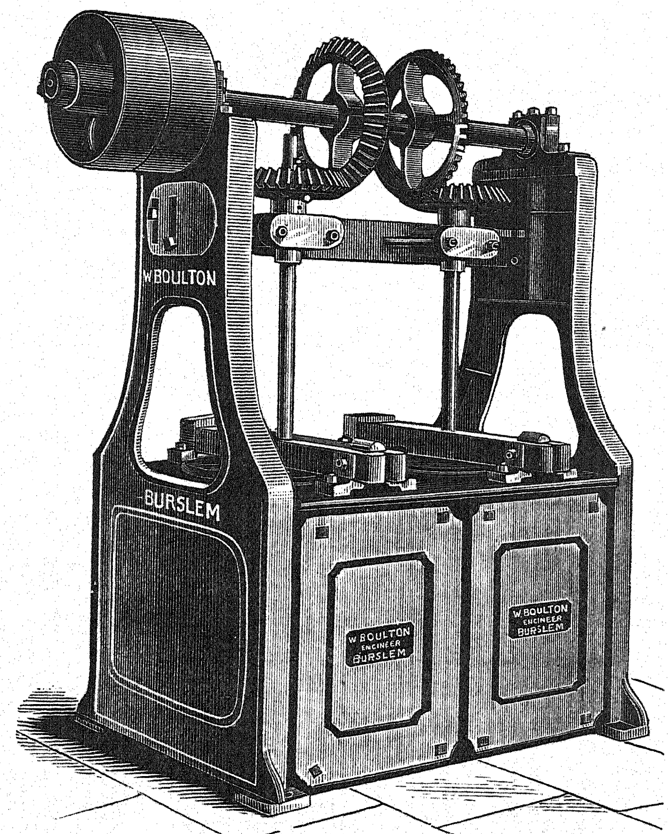


FIG. 268.—Wet-grinding potters' colour-pans. (*By W. Boulton, Ltd., Burslem.*)

really a laboratory appliance for hand-power; the porcelain jar measures only $7\frac{1}{2}$ by $6\frac{1}{2}$ inches inside.

Similar mills are erected in groups or batteries of six or more in a set, and driven by mechanical power.

The illustration of a section of a single-jar mill (fig. 272), kindly lent by the Abbé Engineering Co., will explain the construction and working of ball-mills in general. The grinding-balls may be either rounded flint pebbles from France, South of England, or Greenland, or they may be of porcelain, larger

or smaller, to suit the mill. The frit or material to be ground should be crushed to pass $\frac{1}{8}$-inch mesh sieve prior to entering the mill.

For grinding larger quantities of, say, 400 to 1800 lbs. at a time, the usual potter's glaze-mills may be used. This applies mostly to colourless glazes for white or cream-tinted tiles. These glaze-mills may either be similar to flint-pans (fig. 273), only of smaller diameter, usually from 7 feet to 8 feet 6 inches diameter; or large Alsing cylinders or ball-mills may be used for the purpose.

Coloured glazes may be economically prepared by first grinding a colourless glaze in large quantity on a large pan, and subsequently mixing portions of the colourless glaze with stain or colourant—also in a finely ground state in suspension in water—both glaze and stain being brought to a specified consistence as ascertained by the pint weight, prior to mixture; or both glaze and colour may be separately ground and dried, and then weighed quantities of each mixed together in water.

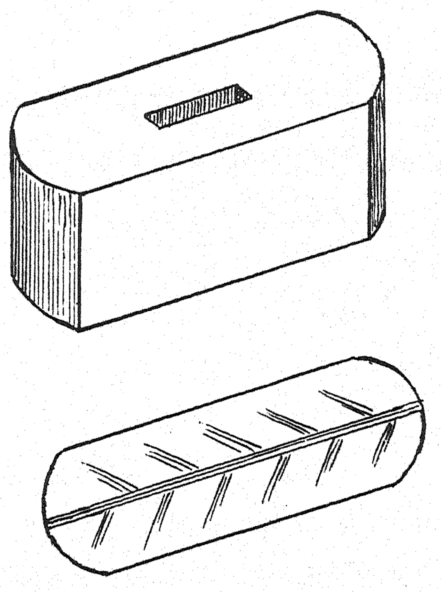


FIG. 269.—Colour-pan muller; also sketch showing the mode of under-grooving.

On account of the desirability of covering tile surfaces much more heavily

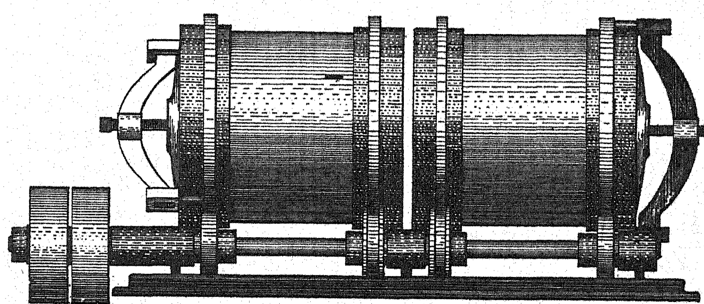


FIG. 270.—No. 0 double-cylinder colour-mill, porcelain lined. (*Crossley Manufacturing Co., Trenton, N.J., U.S.A.*)

with glaze than ordinary earthenware is covered, the glaze is usually not so finely ground. Respecting this point, Mr. Owen Carter has expressed his views and experiences thus:—"English potters have been for some time

fearing the passing of some kind of legislation prohibiting the use of glazes of high solubility as regards lead. The difficulty was that, if one made a frit to meet the proposed Government requirements, an 07 or 08 fire was necessary (our usual heat). It was, therefore, very evident that no raw flotative ingredients could be added, raw lead being forbidden, and soft alkaline frits being impractical for various reasons. The only thing to be done was to use the pure frit, and then came the difficulty of settling, etc. If the frit was ground wet in the usual way, fine enough to keep in suspension in water for dipping, the glaze on the surface of the tiles, when the water had dried out, would become covered with fine cracks, and upon firing the glaze would peel up and collect into beads or patches on the surface, leaving bare places. Thin-dipping, such as is practised with earthenware, would prevent this; but coloured glazes on tiles must be dipped thickly.

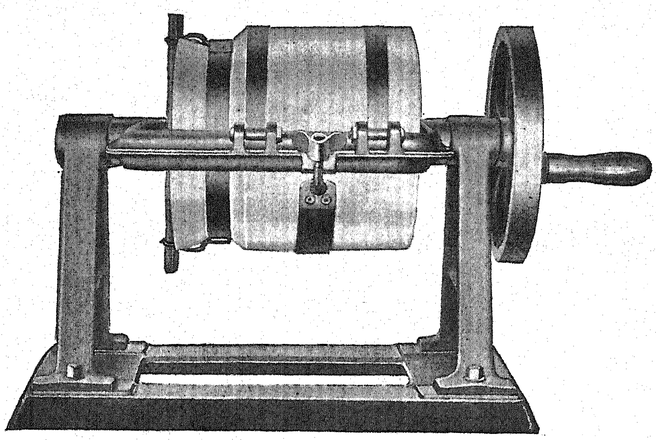


FIG. 271.—The "Little Trojan" mill. (*Abbé Engineering Co., New York.*)

"The solution of the problem was found in grinding the frit dry in Alsing cylinders. I only recollect one case of peeling up with a dry-ground glaze. It seems almost impossible to dry-grind it too finely. I do not say that too fine grinding is in every case the reason of glazes peeling and gathering into patches and beads; but I think that is the usual cause. . . . . Probably two-thirds of the total glaze used at their works is just the pure frit, without the addition of any raw material." (*Trans. A.C.S.*, vol. v .p. 294.)

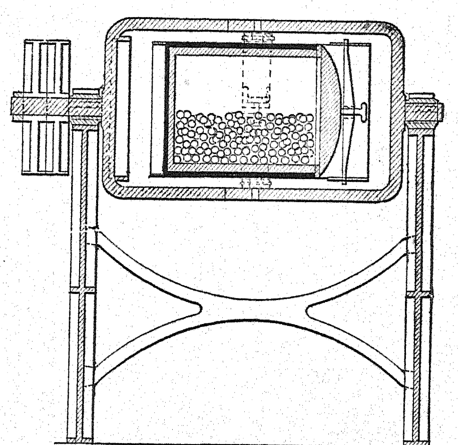


FIG. 272.—Section of single-jar mill. (*Abbé Engineering Co., New York.*)

Another very important advantage in dry-grinding of glaze frits would be

rendering possible the use of many frits that are not eligible for wet-grinding on account of their liability to solution when ground for long periods, which often results in subsequent partially crystallising out of soluble portions. Indeed, it is questionable whether any frit is perfectly stable in this respect, for even feldspar has been found to decompose by long-continued wet-grinding. (See *Trans. A.C.S.*, p. 292, vol. v.)

On account of the risks to employees by dry-grinding, the writer avoided it as much as possible, and has made great efforts to escape such a contingency

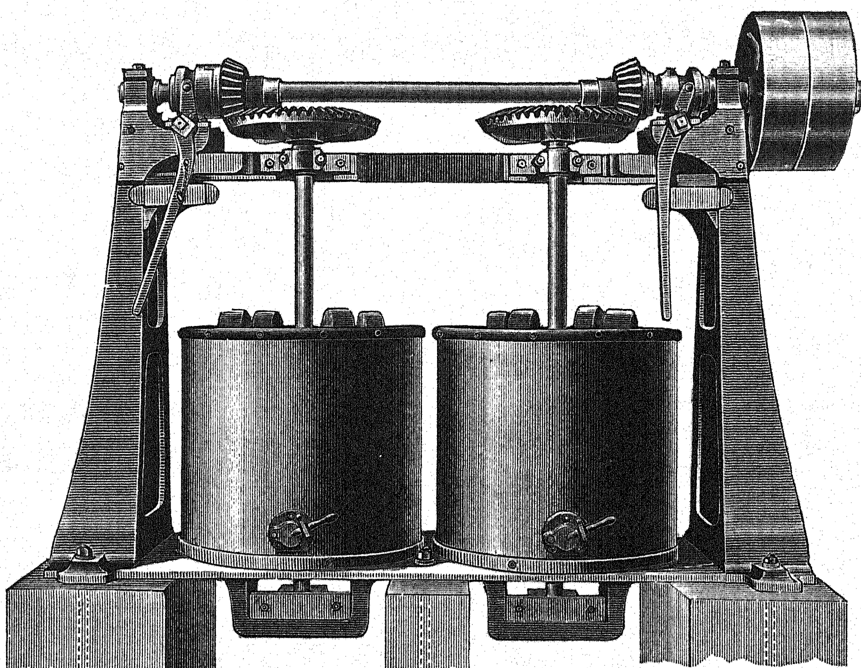


FIG. 273.—Enamel or glaze mills. (*By W. Boulton, Ltd., Burslem.*)

Nevertheless, it is more than probable that many of the softer preliminary trials mentioned in *Researches on Leadless Glazes*, whose only fault was slight opalinity and liability to some degree of decomposition, solution, and recrystallization during wet-grinding, would be completely successful if dry-ground with the addition of a small proportion of alumina to correct opalinity. And probably in very many instances in the following recipes dry-grinding will be a valuable expedient for glazes that have to be dipped thickly to produce the desired effect. When frits are dry-ground in Alsing cylinders or ball-mills in this way, they are subsequently mixed with water and dipped in the usual manner.

To attain the greatest possible perfection and freedom from specks in white glazes, means are taken to extract minute particles of metallic iron which get into the glazes during grinding. This is usually effected by means of magnets. A series may be arranged, hanging from a board, and placed in a trough between two tubs; and as the glaze flows from one to the other through the trough it passes the magnets, which detain the particles of iron—the magnets being afterwards removed and cleaned for future use.

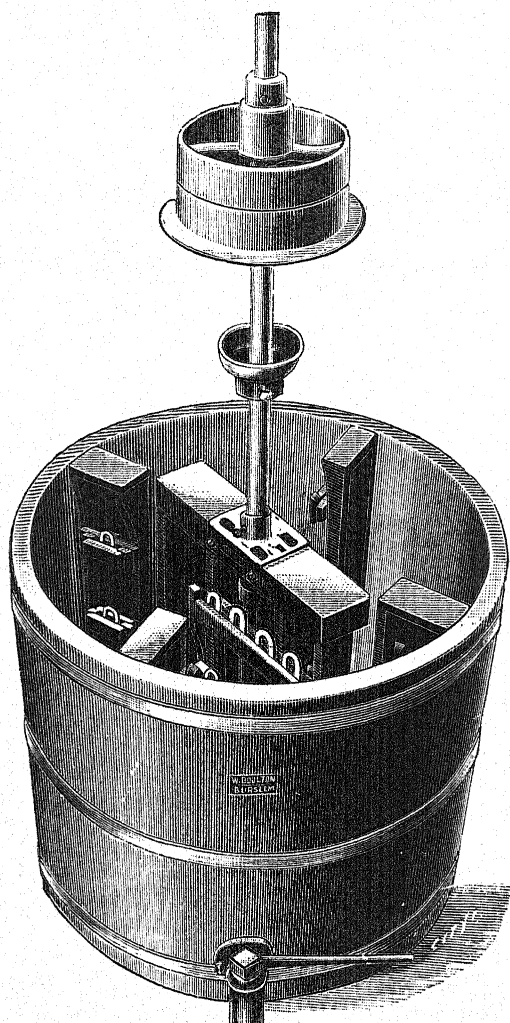


FIG. 274.—Magnetizing machine. (*By W. Boulton, Ltd., Burslem.*)

Electric magnets have sometimes been used, but the slightest momentary cessation of the current caused them to shed their burden, and so they were often unsatisfactory.

Magnetizing machines are also made, so that a charge of glaze may be run into the apparatus or tank, and subjected to the influence of series of magnets in a very thorough manner by rotary movement (see fig. 274).

Glazes for Plain and Printed Tiles.—These usually contain no colourant, and are therefore less liable to injury from hard firing; indeed, it is usual to burn plain and printed glazed tiles either in special kilns or in glost ovens, and take them to a considerably higher temperature than coloured glazes, viz., to about Cone 02, Bar 21, or 1110° C. (2030° Fahrenheit).

In the case of best white-glazed bath and dairy tiles, great care must be exercised to avoid speckiness either in body or glaze, and to avoid flashing during the firing. Separate glaze-dippers' tubs should be used for white tiles, and they should not be dipped in the glaze in which printed tiles have been

dipped. The leadless glazes likely to be most useful for plain white-glazed tiles are Nos. 4, 5, 7, 6, and 8. For printed tiles, suitability to the underglaze colours must be considered. The following are recommended: Nos. 7, 6, and 8.

The writer understands that some glazes used for printed wares in the States mature at Cone 010 (960° C.); this appears too low for durable results. A vigorous correspondent writes in *British Clayworker*, September 1902, p. 203:—"There are no glazes worth their salt for durability—apart from decorative purposes—that come up under 1150° C."

Coloured or Tinted Glazes or Art-Tile Enamels.—During the *régime* of glazes containing considerable proportions of compounds of lead, it has been the necessary custom to burn many coloured glazes or enamels at low temperatures to avoid destroying the colours.

To what extent similar precautions will be required in the absence of lead is perhaps at present by no means fully known, because to render these glazes acceptable to the trade as now carried on, the following recipes have been designed to mature at the regular tile glaze-kiln heats; the possibilities of higher temperatures have, therefore, not yet been fully explored.

The products of the French, German, and English art and architectural stoneware and porcelain ceramists, however, give hope that the low temperatures hitherto customary for glazed-tile kilns, and yielding a product more or less wanting in durability, may not really be necessary; and that as higher burnings are attempted under newer conditions, more durable tiles may be made without the loss of tone in colours hitherto experienced with highly plumbic glazes, whenever temperatures were raised above the customary finishing temperature of "majolica" glazed-tile kilns, which appears to be about 07 Cone (1010° C.).

The following recipes include a considerable assortment of various tints and hues, which may be increased by mixing the several glazes together in various proportions, regard being paid to those glazes that agree well when mixed together.

For it is found that certain colourant oxides are developed into standard tints of coloured glaze by admixture with certain frits or glazes only, and that the same proportions of other glazes very greatly alter the colour attainable by use of the same colourant; hence mixing of glazes should only be done after experiment has demonstrated their suitability.

The names by which the colours, hues, or tints are distinguished cannot, however, be taken as an altogether safe guide. Many terms used in the trade are applied without definiteness, and the name given to a tint by one maker may not correspond with that of another. In the main, however, the usual designations have been followed; and in Plate XXXIII. some of the colours

have been illustrated and named as nearly as the processes of illustration permitted.

Tinted glazes may, of course, be caused to yield different results by being applied to bodies of different colour; for just as the effect of colourless glazes is enormously influenced by the colour of body upon which it is applied, so are tinted glazes. For instance, a dark blue glaze applied on red body yields a black effect. Indian potters are said to have made good use of this expedient by glazing in a green-tinted glaze red wares already ornamented with white slips.

For glaze stains or colourants it is not always necessary or advantageous to use complex, finely prepared chemical colourants, nor always best to calcine these prior to use. Excellent tints are furnished by simply grinding together common articles of commerce with suitable glazes. Indeed, on more than one occasion it has apparently been a matter of self-satisfaction with eminently practical persons engaged in the decorative-tile trade that the ingredients they used were of the cheapest.

In several cases the action of the soft glazes would merely undo again the most carefully contrived and finely balanced chemically prepared colourants such as are used for enamel colours upon glazed china, and thus the manipulation of such colours for our purposes would be wasted labour. This is particularly so, because one of the aims of the decorative-tile maker is to produce tinted glazes of the greatest attainable transparency; and the more perfect solution tends to destroy all previous combinations.

In the case of what are called enamelled tiles and faience, in which different-coloured glazes are applied by means of the brush to different parts of the same piece, so as to form a design in polychrome, it is important that each of the glazes associated upon any one tile or piece shall mature approximately under the same conditions and temperature. If one glaze would suit all colourants, this would not be difficult of attainment; but as the different colourants exhibit preferences, so to speak, the arrangement and compensations necessary to get the best possible results out of each, at one time and temperature, tax the resources of the ceramist in the case of leadless glazes, precisely as they have hitherto done in the case of lead glazes. Still, this is no *greater* hardship.

The only way to work out this problem satisfactorily is to apply all the glazes in small patches on one slab, duplicate this slab and burn in different parts of the kiln, and select according to results.

Costs.—The actual cost of glazes fluctuates incessantly according to market prices of the ingredients; for that reason the following specimen calculations can only be considered provisional and approximate. An important part of the reckoning consists of estimating the loss by volatilization of moisture, chemically combined water and gases; and as these losses are

moderately steady, a list has been prepared showing the factors required in the calculations, allowance having been made for minor contingencies.

	Probable Loss during Fritting.	Estimated Yield from the Frit Kiln.	Calculation Factor.
	Per cent.	Per cent.	
Felspar, ground, ...	3	97	·97
Cornish stone, ground, . . .	6	94	·94
Calcined flint, ground, . . .	4	96	·96
Whitening, ...	47	53	·53
China-clay, ...	23	77	·77
Soda-ash, ...	42	58	·58
Boracic acid, ...	45	55	·55
Borax, ...	47	53	·53

For an example, take No. 6 colourless glaze.

FRIT.			£	s.	d.	ESTD. YIELD.
10½ cwts.	borax	at 16s. per cwt., . .	8	8	0	5·56 cwts.
1½ ,,	soda-ash	,, 4s. ,, . .	0	6	0	·87 ,,
2 ,,	felspar	,, 5s. ,, . .	0	10	0	1·94 ,,
9¼ ,,	stone	,, 3s. ,, . .	1	7	9	8·69 ,,
7 ,,	flint	,, 2s. ,, . .	0	14	0	6·72 ,,
7 ,,	whitening	,, 2s. ,, . .	0	14	0	3·71 ,,
4½ ,,	china-clay	,, 2s. ,, . .	0	9	0	3·46 ,,
41¾ cwts.			£12	8	9	30·95 cwts.
		Fritting, etc., at 1s. 6d. per cwt.,	3	2	3	
			£15	11	0	or practically 10s. per cwt. of the yield.

GLAZE.	£	s.	d.	£	s.	d.	
10 cwts. fritt at 10s., ...	5	0	0				
1 ,, clay ,, 2s., ...	0	2	0	=7	14	0	That is 14s. per cwt., or allowing for losses in process, say 15s. per cwt.
Grinding, ...	2	2	0				

Another example may be No. 2 colourless glaze.

FRIT.			£	s.	d.	ESTD. YIELD.
10 cwts.	borax	at 16s. per cwt., ...	8	0	0	5 cwts.
2 ,,	soda-ash	,, 4s. ,, ...	0	8	0	1 ,,
8 ,,	flint	,, 2s. ,, ...	0	16	0	7½ ,,
4 ,,	whitening	,, 2s. ,, ...	0	8	0	2 ,,
4 ,,	china-clay	,, 2s. ,, ...	0	8	0	3 ,,
28 cwts.			£10	0	0	18½ cwts.
		Fritting, etc., at 1s. 6d. per cwt.,	2	2	0	
			£12	2	0	

Hence 18½ cwts. costs £12, 2s.; therefore 1 cwt. costs 13s. 6d.

Glaze.		£	s.	d.
8 cwts. frit	at 13s. 6d. per cwt.,	5	8	0
½ ,, calcined alumina	,, 25s. ,,	0	12	6
Grinding,		1	14	0
		£7	14	6
Drying, say,		0	8	6
		£8	3	0

Costs, say, 20s. per cwt.

But to make a just comparison, it is necessary to take into consideration the relative covering power, because, by reason of the lower specific gravity of leadless glazes, it has been found in practice that weight for weight they cover considerably more ware than lead glazes.

Roscoe gives the following sp. gr:—White-lead, 6·47; red-lead, 8·53; lead glass, 3·0–3·8; soda-lime glass, 2·4–2·6; borax fused to glassy condition, 2·367; fused boracic acid, 1·83; hence in glazes containing such a high percentage of lead compounds as those in use for tiles and faience often between 47 and 57 per cent. The effect on cost in respect of sp. gr. is likely to be very great.

Of course, great differences can be made in the weight of dry glaze upon a tile by thickly or thinly dipping; and, no doubt, there is opportunity sometimes for economy in that way; but, quite apart from that, the difference of sp. gr., which may be as much as 2·1, must create very great possibility of economy.

In practice it has been found that 1 oz. of dry leadless glaze sufficiently covers a 6-inch by 6-inch tile, for 8 drs. covered a 6-inch by 3-inch tile.

In cases where economy is of importance, a careful consideration of the notes on the influence of soda should be undertaken. As a rule, however, the first cost of a glaze is secondary in comparision with the output of the greatest proportion of best goods. After years of experience with leadless glazes for the manufacture of earthenware, one manufacturer vouchsafed the statement that more good ware went into his warehouse than during the time he used lead glazes; there are, therefore, some grounds for anticipating similarly favourable results when leadless glazes are fairly tested on tiles.

Maturing or Melting Points.—As a final check upon the following recipes before publication, it was determined to submit specimens of the most important frits and fluxes to an independent and impartial scientific determination of their respective melting-points. This work was entrusted to Mr. W. Jackson, A.R.C.S., lecturer on pottery and porcelain to the Staffordshire County Council, with the following results:—

			Temp. of Complete Fusion.
*No. 1.	Colourless frit,		700° C.
*No. 1.	,,	,, another batch,	750° C.
*No. 1.	,,	,, ,,	850° C.
*No. 2.	,,	,,	850° C.
No. 3.	,,	,,	750° C.
No. 5.	,,	,,	700° C.
No. 6.	,,	,,	720° C.
No. 8.	,,	,,	800° C.
No. 11.	,,	,,	770° C.
No. 13.	,,	,,	825° C.
No. 14.	,,	,,	720° C.
No. 1.	,,	glaze,	900° C.

* The great difference in fusing temperature in these probably is caused by either flint off the crucibles, or some additions made to facilitate grinding by the wet method, in some cases.

Experimental errors would unavoidably enter into the determinations arising from differences in speed of getting up heat, differences in physical condition of specimens, etc., etc.; but the figures may with perfect justice be put forward as the results of actual observations by a trained observer working with a thermo-electrical pyrometer, and testing a not inconsiderable variety of compositions in the form of frits, all of them free from lead compounds. Now, let it be noted that a usual finishing temperature for the easily fusible "soft" decorative-tile glazes is Cone 07 = 1010° C; it will then be seen that these scientific tests completely substantiate the claim that lead-free glazes of sufficiently low-fusion temperature are possible.

Chemical Formulæ.—It was at one time intended to attach the chemical formula to each of the recipes for the colourless frits and glazes, but upon further consideration, and in view of the fact that the recipes in most instances had been discovered by purely empirical methods, it appeared unnecessary to put in the formulæ, and they were accordingly struck off the manuscript.

Besides, a ceramic recipe cannot be accurately and always represented by a definite chemical formula, by reason of the small fluctuations constantly arising in the chemical composition of the several ingredients found in commerce, and numberless little perturbations resulting from accidents in the processes of preparation of the frits.

Confirmation of this view of the subject is supplied by the admitted necessity for corrections in the standardizing of pyrometric cones, and by Mr. Jackson's notes, p. 24, *Ceramic Calculations*, already referred to. Then, again, it does not follow that compositions made up by the chemical formulæ, but from different ingredients used according to their analyses, would yield frits possessing precisely similar qualities to those obtainable by the empirical or practical recipes given; hence as the chemical formulæ are only useful to those who clearly understand their limitations, and who can easily

calculate them for themselves, they have been omitted from the following practical recipes.

RECIPES FOR COLOURLESS FRITS.

No. 1.—Colourless Frit.

20 lbs.	refined borax crystals.	Crush and sieve each ingredient separately. Then weigh the batch, mix thoroughly, and sieve again. Melt to a glassy frit either in crucibles or frit kiln.
16 „	ground calcined flint.	
8 „	„ whitening.	
8 „	Cornish china-clay.	
4 „	soda-ash.	

No. 2.—Colourless Frit.

24 lbs.	refined borax crystals.	Treat as No. 1.
16 „	ground silica rock.	
8 „	„ whitening.	
6 „	Cornish china-clay.	
4 „	soda-ash.	

No. 3.—Colourless Frit.

24 lbs.	refined borax crystals.	Treat as No. 1.
12 „	ground calcined flint.	
11 „	„ whitening.	
11 „	„ Cornish china-stone.	
4 „	Cornish china-clay.	

No. 4.—Colourless Frit (equivalent to the Cremer frit).

20 lbs.	refined borax crystals.	Treat as No. 1.
12 „	ground calcined flint.	
5 „	„ whitening.	

No. 5.—Colourless Frit.

20 lbs.	refined borax crystals.	Treat as No. 1.
12 „	ground silica rock.	
4 „	Cornish china-clay.	
4 „	soda-ash.	
4 „	white oxide zinc.	

Note.—This yields a water-white frit and melts easily. Being free from lime, it is serviceable in cases where calcium prevents the most elegant development of a colourant.

No. 6.—Colourless Frit.

20	lbs.	refined borax crystals.	Treat as No. 1.
8	,,	ground silica rock.	
4	,,	Cornish china-stone.	
4	,,	ground whitening.	
3	,,	white oxide of zinc.	
1	,,	soda-ash.	

No. 7.—Colourless Frit.

240	lbs.	refined borax crystals.	Treat as No. 1. *Preferably "run down" on a frit kiln.*
160	,,	ground felspar.	
160	,,	Cornish china-stone.	
80	,,	ground calcined flint.	
80	,,	,, whitening.	
20	,,	Cornish china-clay.	

No. 8.—Colourless Frit.

220	lbs.	refined borax crystals.	Treat as No. 1. *Preferably "run down" on a frit kiln.*
180	,,	Cornish china-stone.	
120	,,	ground calcined flint.	
120	,,	,, whitening.	
80	,,	,, felspar.	
60	,,	Cornish china-clay.	
20	,,	soda-ash.	

No. 9.—Colourless Frit.

210	lbs.	refined borax crystals.	Melt or "run down" on a frit kiln.
30	,,	soda-ash.	
40	,,	ground felspar.	
185	,,	Cornish china-stone.	
140	,,	ground calcined flint.	
140	,,	,, whitening.	
90	,,	Cornish china-clay.	

No. 10.—Colourless Frit.

210	lbs.	refined borax crystals.	Melt or "run down" on a frit kiln.
30	,,	soda-ash.	
40	,,	ground felspar.	
185	,,	Cornish china-stone.	
140	,,	ground silica rock.	
140	,,	,, whitening.	
90	,,	Cornish china-clay.	

No. 11.—Colourless Frit.

200 lbs.	refined borax crystals.	Melt or "run down" on a frit kiln.
190 „	Cornish china-stone.	
160 „	ground calcined flint.	
160 „	„ whitening.	
120 „	Cornish china-clay.	
40 „	soda-ash.	

No. 12.—Colourless Frit.

180 lbs.	refined borax crystals.	Melt on a frit kiln at highest attainable heat.
360 „	Cornish china-stone.	
90 „	ground calcined flint.	

No. 13.—Colourless Frit.

140 lbs.	refined boracic acid.	Melt either in saggars or on a frit kiln.
60 „	soda-ash.	
150 „	Cornish china-stone.	
60 „	ground calcined flint.	
100 „	„ whitening.	
26 „	Cornish china-clay.	

No. 14.—Colourless Frit or Flux.

20 lbs.	refined borax crystals.	Run down in flux kiln.
8 „	ground silica rock.	
4 „	Cornish china-stone.	
4 „	ground whitening.	
1 „	soda-ash.	

No. 15.—Soda-Lime Glass Frit.

80 lbs.	ground silica rock.	Mix intimately and frit in saggars in a biscuit oven.
25 „	soda-ash.	
15 „	ground whitening.	

No. 16.—Colourless Frit or Flux.

112 lbs.	powdered borax crystals.	Frit on frit kiln three hours.
56 „	ground silica.	
7 „	„ biscuit pitchers.	

RECIPES FOR TRANSPARENT COLOURLESS GLAZES.

No. 1.—Colourless Glaze (for muffled-kiln heat).

100 lbs. colourless frit No. 1. 10 „ Cornish china-clay.	For thin-dipping, grind in water on a potter's glaze-pan, or a cleaned colour-pan. For thick-dipping, grind dry in a pebble-mill, and afterwards mix with water to a suitable consistence.

No. 2.—Colourless Glaze.

96 lbs. colourless frit No. 1. 6 „ calcined alumina.	Grind as No. 1.

No. 3.—Colourless Glaze.

20 lbs. colourless frit No. 2. 1 „ calcined alumina.	Grind as No. 1.

No. 4.—Colourless Glaze.

100 lbs. colourless frit No. 7. 5 „ alumina hydrate.	Grind in water on a potter's glaze-pan.

Note.—Large quantities of this glaze have been used on bone china.

No. 5.—Colourless Glaze.

100 lbs. colourless frit No. 8. 10 „ alumina hydrate.	Grind in water on a potter's glaze-pan.

No. 6.—Colourless Glaze.

100 lbs. colourless frit No. 9. 10 „ Cornish china-clay.	Grind in water on a potter's glaze-pan.

Note.—This is an excellent glaze for printed ware or tiles.

No. 7.—Colourless Glaze.

800 lbs. colourless frit No. 10. 50 „ Cornish china-clay. 10 „ ground silica rock. 10 „ Cornish china-stone.	Grind in water on a potter's glaze-pan.

Note.—The author highly recommends this glaze for printed ware and tiles

No. 8.—Colourless Glaze.

1000 lbs.	colourless frit No. 11.	Grind in water on a potter's glaze-pan.
100 „	Cornish china-clay.	

No. 9.—Colourless Glaze.

1200 lbs.	colourless frit No. 11.	Grind in water on a potter's glaze-pan.
40 „	Cornish china-clay.	
40 „	ground felspar.	
40 „	soft china-stone.	

Note.—Very large quantities of this glaze have been used for earthenware.

No. 10.—Colourless Glaze.

1200 lbs.	colourless frit No. 12.	Grind in water on a potter's glaze-pan.
120 „	Cornish china-clay.	

Note.—Large quantities of this glaze have been used for earthenware.

No. 11.—Colourless Glaze.

1200 lbs.	colourless frit No. 12.	Grind in water on a potter's glaze-pan.
60 „	Cornish china-clay.	
60 „	„ china-stone.	

Note.—This glaze is particularly suitable for U.G. matt-blue.

No. 12.—Colourless Glaze.

10 lbs.	colourless frit No. 3.	Grind as No. 1.
1 „	Cornish china-clay.	

No. 13.—Colourless Glaze.

198 lbs.	colourless frit No. 13.	Grind in water on a potter's glaze-pan.
45 „	Cornish china-stone.	
9 „	ground calcined flint.	
9 „	„ whitening.	

RECIPES FOR LIGHT IVORY-TINTED GLAZES.

No. 1.—Ivory-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless frit No. 1.	For thin-dipping, grind on a potter's glaze-pan. For thick-dipping, grind dry in a pebble-mill, and afterwards mix with water to a suitable consistence.
$1\frac{1}{2}$ „	calcined alumina.	
3 „	Japanese red.	

No. 2.—Ivory-Tinted Glaze.

16 lbs.	colourless glaze No. 12.	Grind as No. 1.
$1\frac{1}{2}$ „	calcined alumina.	
3 „	Japanese red.	

No. 3.—Ivory-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless glaze No. 1.	Grind as No. 1.
$\frac{1}{2}$ „	native oxide of titanium.	
$\frac{1}{4}$ „	borate of lime.	
$\frac{1}{4}$ „	ivory ball-clay.	

RECIPE FOR MAIZE-TINTED OR INDIAN-YELLOW GLAZE.

No. 1.—Maize-Tinted Glaze (for muffled-kiln heat.)

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
$\frac{1}{2}$ „	calcined alumina.	
3 „	chocolate flooring-tile pitcher.	

RECIPES FOR YELLOW-TINTED GLAZES.

No. 1.—Lemon-Yellow-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	uranium oxide.	
$\frac{1}{4}$ „	ground calcined ironstone.	
$\frac{1}{4}$ „	stain, as under.	

Stain.

2 lbs.	red oxide of iron	ground together in water on a potter's colour-pan.
$1\frac{1}{4}$ „	black oxide of copper	
1 „	cryolite	
$\frac{1}{4}$ „	fluor-spar	

No. 2.—Primrose-Yellow-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
$\frac{1}{2}$ „	uranium oxide.	
$\frac{1}{2}$ „	yellow ironstone (Desborough, Northampton).	
$\frac{1}{4}$ „	borate of calcium.	

No. 3.—Primrose-Yellow-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
$\frac{1}{2}$ „	calcined alumina.	
$\frac{1}{2}$ „	uranium oxide.	
$\frac{1}{2}$ „	yellow ironstone (Desborough).	

No. 4.—Canary-Yellow-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	uranium oxide.	
$\frac{1}{4}$ „	borate of calcium.	

No. 5.—Canary-Yellow-Tinted Glaze.

16 lbs.	colourless frit No. 2.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	uranium oxide.	
$\frac{1}{4}$ „	borate of calcium.	

RECIPES FOR TAN AND KHAKI TINTED GLAZES.

No. 1.—Tan or Maple Tinted Glaze (for muffle).

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory-tinted glaze.
3 „	black flooring-tile pitchers.	
$\frac{1}{2}$ „	calcined alumina.	

Note.—If high-class product required, "run down" in a flux kiln prior to grinding.

No. 2.—Khaki-Coloured Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory-tinted glaze.
1 „	calcined alumina.	
$\frac{3}{4}$ „	ground calcined ironstone.	
$\frac{3}{4}$ „	„ common manganese ore.	
$\frac{1}{8}$ „	black oxide of copper.	

No. 3.—Khaki-Coloured Glaze.

16 lbs.	colourless glaze No. 1	Grind as No. 1 ivory glaze.
$\frac{1}{2}$ „	calcined alumina.	
$\frac{3}{4}$ „	ground manganese ore (common quality).	
$\frac{1}{2}$ „	uranium oxide.	

RECIPES FOR AMBER-TINTED GLAZES.

No. 1.—Amber-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	„ ironstone.	
½ „	common manganese ore.	
¼ „	uranium oxide, yellow.	

No. 2.—Amber-Tinted Glaze.

16 lbs.	colourless frit No. 1.	Grind dry in pebble-mill and afterwards mix with water for dipping.
¾ „	calcined alumina.	
1 „	„ ironstone.	
¼ „	common manganese ore.	
¼ „	uranium oxide, yellow.	
¼ „	zinc oxide.	
⅛ „	common salt.	
⅛ „	fluor-spar.	

RECIPES FOR GOLDEN-ORANGE-TINTED GLAZES.

No. 1.—Golden-Orange-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1½ „	„ ironstone.	
½ „	uranium oxide, yellow.	
¼ „	common manganese ore.	
¼ „	calcium borate.	

No. 2.—Golden-Orange-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1½ „	„ ironstone.	
½ „	uranium oxide, yellow.	
½ „	common manganese ore.	

No. 3.—Golden-Orange-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
½ „	calcined alumina.	
1½ „	„ ironstone.	
1 „	uranium oxide, yellow.	
½ „	calcium borate.	
⅛ „	common manganese ore.	

No. 4.—Golden-Orange-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
½ "	calcined alumina.	
1½ "	" ironstone.	
1 "	uranium oxide, yellow.	
1¼ "	cryolite.	
½ "	calcium borate.	
⅛ "	common manganese ore.	

RECIPES FOR FAWN-TINTED GLAZES.

No. 1.—Fawn-Tinted Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 "	calcined alumina.	
1 "	pure hydrate of manganese.	
1 "	white oxide of zinc.	

No. 2.—Fawn-Tinted Glaze.

16 lbs.	colourless frit No. 1.	Grind dry in a pebble-mill and afterwards mix with water to suitable consistence.
1 "	calcined alumina.	
½ "	carbonate of manganese.	
½ "	calcium borate.	
1 oz.	cobalt phosphate.	

No. 3.—Fawn-Tinted Glaze.

16 lbs.	colourless glaze No. 1.	Grind dry in a pebble-mill and afterwards mix with water to suitable consistence.
1 "	calcined alumina.	
½ "	carbonate of manganese.	
¼ "	common salt.	

RECIPES FOR GOLDEN-BROWN-TINTED GLAZES.

No. 1.—Golden-Brown-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1½ "	calcined ironstone.	
½ "	common manganese ore.	

No. 2.—Golden-Brown-Tinted Glaze (for muffled-kiln heat).

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1½ "	manganese ore, common.	
1½ "	refined Anglesea ochre.	
1 "	calcined alumina.	

No 3.—Golden-Brown-Tinted Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
$1\frac{1}{2}$ „	manganese ore, common.	
$1\frac{1}{2}$ „	calcined ironstone.	
$\frac{1}{4}$ „	white oxide of zinc.	

No. 4.—Golden-Brown-Tinted Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
2 „	common manganese ore.	
$1\frac{1}{2}$ „	calcined ironstone.	

RECIPES FOR CHESTNUT AND BAY-BROWN TINTED GLAZES.

No. 1.—Chestnut-Brown Glaze (for muffled-kiln heat).

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
$\frac{3}{4}$ „	calcined alumina.	
$\frac{3}{4}$ „	manganese chromate.	

No. 2.—Chestnut-Brown Glaze (see No. 3 fawn).

16 lbs.	colourless glaze No. 1.	Grind dry on pebble-mill and afterwards mix with water.
1 „	calcined alumina.	
$\frac{1}{2}$ „	carbonate of manganese.	
$\frac{1}{4}$ „	common salt.	

No. 3.—Bay-Brown Glaze (for muffled-kiln heat).

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	hydrate of manganese.	
$\frac{1}{4}$ „	nitre.	

RECIPES FOR LEATHER-BROWN-TINTED GLAZES.

No. 1.—Leather-Brown Glaze (for muffled-kiln heat).

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	hydrate of manganese.	
1 oz.	black oxide of cobalt.	

No. 2.—Leather-Brown Glaze.

16 lbs.	colourless glaze No. 5.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	hydrate of manganese.	

RECIPES FOR TEAPOT OR ROCKINGHAM BROWN GLAZES.

No. 1.—Teapot-Brown Glaze.

16 lbs.	colourless glaze No. 12.	Grind as No. 1 ivory glaze.
$1\frac{1}{2}$ „	calcined alumina.	
3 „	carbonate of manganese.	

No. 2.—Teapot-Brown Glaze.

16 lbs.	colourless glaze No. 12.	Grind as No. 1 ivory glaze.
$1\frac{1}{2}$ „	calcined alumina.	
$2\frac{1}{2}$ „	black oxide of manganese.	

No. 3.—Teapot-Brown Glaze.

16 lbs.	colourless glaze No. 12.	Grind as No. 1 ivory glaze.
2 „	calcined alumina.	
3 „	carbonate of manganese, pure.	
2 „	calcium borate.	

No. 4.—Teapot or Sealskin Brown Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
$1\frac{1}{2}$ „	common manganese ore.	
$1\frac{1}{2}$ „	calcined ironstone.	
1 „	„ alumina.	

No. 5.—Rockingham-Brown Glaze (for oven fire).

14 lbs.	colourless frit No. 6.	Grind as No. 1 ivory glaze.
4 „	common manganese ore.	
1 „	calcined alumina.	
1 „	soda-ash.	

No. 6.—Rockingham-Brown Glaze (for muffled-kiln fire).

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
$1\frac{1}{2}$ „	calcined alumina.	
3 „	common manganese ore.	

No. 7.—Light Rockingham-Brown Glaze.

48 lbs. colourless glaze No. 1.		Grind as No. 1 ivory glaze.
$2\frac{1}{2}$ „ common manganese ore.		
2 „ calcined ironstone.		
1 „ cryolite.		
$\frac{1}{2}$ „ calcined alumina.		
$\frac{1}{2}$ „ soda-ash.		

RECIPES FOR LIGHT MADDER-TINTED GLAZES.

No. 1.—Light Madder-Tinted Glaze (for muffled-kiln heat).

16 lbs. colourless glaze No. 1.	For superior effects "run down" in flux kiln before grinding. Otherwise grind as No. 1 ivory glaze.
1 „ calcined alumina.	
$\frac{1}{2}$ „ pure manganese hydrate.	
$\frac{1}{2}$ oz. black oxide of cobalt.	

No. 2.—Light Madder-Tinted Glaze (for muffled-kiln heat).

16 lbs. colourless frit No. 4.	Treat as No. 1 light madder glaze.
2 „ calcined alumina.	
1 „ pure manganese hydrate.	

No. 3.—Light Madder-Tinted Glaze (for muffled-kiln heat).

16 lbs. colourless frit No. 1.	Treat as No. 1 light madder glaze.
1 „ calcined alumina.	
2 „ stain, as under.	

Stain.

10 lbs. felspar	mixed, and calcined in biscuit oven.
5 „ permanganate of potash	

RECIPES FOR LIGHT PLUM-TINTED GLAZES.

No. 1.—Light Plum-Tinted Glaze.

16 lbs. colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „ calcined alumina.	
$\frac{1}{2}$ „ carbonate of manganese, commercial.	
$\frac{1}{2}$ oz. black oxide of cobalt.	

No. 2.—Light Plum-Tinted Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 ,,	calcined alumina.	
1 ,,	pure hydrate of manganese.	
1 oz.	black oxide of cobalt.	

No. 3.—Light Plum-Tinted Glaze.

22 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 ,,	calcined alumina.	
4 ozs.	manganese ore (85 per cent. MnO_2).	
½ ,,	black oxide of cobalt.	

RECIPES FOR UMBER-BROWN GLAZES.

No. 1.—Umber-Brown Glaze (for muffled-kiln heat).

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 ,,	calcined alumina.	
½ ,,	pure hydrate of manganese.	
⅛ ,,	carbonate of copper.	

No. 2.—Umber-Brown Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
2½ ,,	calcined alumina.	
½ ,,	common manganese ore.	
⅛ ,,	carbonate of copper.	

RECIPES FOR BROWN-BRONZE GLAZES.

No. 1.—Brown-Bronze Glaze.

64 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
6 ,,	calcined ironstone.	
2 ,,	oxide of copper.	
3 ,,	calcined alumina.	
1 ,,	uranium oxide.	

No. 2.—Brown-Bronze Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
½ ,,	calcined alumina.	
1¼ ,,	calcined ironstone.	
½ ,,	oxide of copper.	
½ ,,	,, uranium.	

RECIPES FOR OLD-GOLD-TINTED GLAZES.

NO. 1.—OLD-GOLD-TINTED GLAZE (for muffled-kiln heat).

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1½ „	„ ironstone.	
½ „	stain, as under.	

Stain.

2 lbs.	red oxide of iron	ground in water in a potter's colour-pan and dried.
1¼ „	black oxide of copper	
1 „	cryolite	
¼ „	fluor-spar	

NO. 2.—OLD-GOLD-TINTED GLAZE (for muffled-kiln heat).

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
¾ „	calcined alumina.	
1¼ „	uranium oxide, yellow.	
¾ „	calcined ironstone.	
¾ „	stain as for No. 1 above.	

NO. 3.—OLD-GOLD-TINTED GLAZE (for muffled-kiln heat).

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1½ „	uranium oxide, yellow.	
¾ „	calcined ironstone.	
¾ „	stain as for No. 1 above.	

RECIPE FOR GOLDEN-GREEN OR CITRON TINTED GLAZE.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory-tinted glaze.
1 „	calcined alumina.	
1 „	uranium oxide, yellow.	
½ „	calcined ironstone.	
½ „	stain as for No. 1 old-gold glaze.	

RECIPES FOR OLIVE-GREEN-TINTED GLAZES.

NO. 1.—OLIVE-GREEN GLAZE (for muffled-kiln heat).

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
3 „	stain as for No. 1 old-gold.	
½ „	calcined alumina.	

No. 2.—Olive-Green Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1. ivory glaze.
½ „	calcined alumina.	
1 „	calcined ironstone.	
¾ „	common manganese ore.	
½ „	black oxide of copper.	
½ „	common salt.	

RECIPES FOR MOSS-GREEN GLAZES.

No. 1.—Moss-Green Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1¼ „	red oxide of iron.	
1¼ „	black oxide of copper.	

No. 2.—Moss-Green Glaze (suggestion).

15 lbs.	colourless frit No. 6.	Grind as No. 1 ivory glaze.
2 „	red oxide of iron.	
1¼ „	black oxide of copper.	
1 „	cryolite.	
½ „	calcined alumina.	
¼ „	fluor-spar.	

RECIPES FOR BRONZE-GREEN GLAZES.

No. 1.—Light Bronze-Green Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
10 ozs.	„ ironstone.	
3 „	black oxide of copper.	

No. 2.—Light Bronze-Green Glaze.

18 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
¾ „	calcined ironstone	
¾ „	„ alumina.	
¼ „	carbonate of copper.	
⅛ „	common salt.	

No. 3.—Bronze-Green Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined ironstone.	
1 „	black oxide of copper.	
½ „	calcined alumina.	

No. 4.—Bronze-Green Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	stain, as under.	
¼ „	uranium oxide.	
¼ „	calcined ironstone.	

Stain.

13 lbs.	dark red oxide of iron	ground in water on a potter's colour-pan and afterwards dried.
5 „	black oxide of copper	
6 „	cryolite	
1 „	fluor-spar	
1 „	oxide of cobalt	

No. 5.—Bronze-Green Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	stain as for No. 4.	
⅛ „	uranium oxide.	

No. 6.—Bronze-Green Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1¼ „	„ ironstone.	
¾ „	black oxide of copper.	

RECIPES FOR SEA-GREEN-TINTED GLAZES.

No. 1.—Sea-Green-Tinted Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	stain as for No. 4 bronze-green.	

No. 2.—Sea-Green-Tinted Glaze.

18 lbs.	colourless glaze No. 1.		Grind as No. 1 ivory glaze.
1	„	calcined alumina.	
$1\frac{1}{4}$	„	„ ironstone.	
1	„	black oxide of copper.	

RECIPES FOR MEADOW-GREEN GLAZES.

No. 1.—Meadow-Green Glaze.

16 lbs.	colourless glaze No. 1.		Grind as No. 1 ivory glaze.
1	„	calcined alumina.	
$\frac{1}{2}$	„	„ ironstone.	
$\frac{1}{8}$	„	black oxide of copper.	

No. 2.—Meadow-Green Glaze.

18 lbs.	colourless frit No. 6.		Grind as No. 1 ivory glaze.
1	„	calcined alumina.	
$\frac{1}{2}$	„	Anglesea ochre.	
$\frac{1}{2}$	„	uranium oxide, yellow.	
$\frac{1}{4}$	„	black oxide of copper.	

RECIPES FOR GRASS-GREEN GLAZES.

No. 1.—Grass-Green Glaze.

16 lbs.	colourless glaze No. 1.		Grind as No. 1 ivory glaze.
1	„	calcined alumina.	
$\frac{1}{2}$	„	oxide of uranium, yellow.	
$\frac{1}{2}$	„	oxide of copper.	
$\frac{1}{2}$	„	common manganese ore.	

No. 2.—Grass-Green Glaze.

16 lbs.	colourless glaze No. 1.		Grind as No. 1 ivory glaze.
1	„	calcined alumina.	
1	„	black oxide of copper.	
1	„	white oxide of zinc.	

RECIPES FOR APPLE-GREEN GLAZES.

No. 1.—Light Apple-Green Glaze.

16 lbs.	colourless glaze No. 1.		Grind as No. 1 ivory glaze.
1	„	calcined alumina.	
$\frac{1}{2}$	„	uranium oxide, yellow.	
$\frac{1}{4}$	„	black oxide of copper.	

No. 2.—Light Apple-Green Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
$\frac{3}{4}$ „	uranium oxide, yellow.	
$\frac{3}{4}$ „	black oxide of copper.	

No. 3.—Dark Apple-Green Glaze.

15 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	uranium oxide, yellow.	
$\frac{1}{2}$ „	black oxide of copper.	

RECIPE FOR EMERALD-GREEN GLAZE.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
$1\frac{1}{4}$ „	calcined alumina.	
1 „	uranium oxide, yellow.	
$\frac{1}{2}$ „	black oxide of copper.	

RECIPES FOR CHINESE-GREEN GLAZES.

No. 1.—Chinese-Green Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
$1\frac{1}{4}$ „	calcined alumina.	
1 „	vitreous green floor-tile.	

No. 2.—Chinese-Green Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
$1\frac{1}{4}$ „	calcined alumina.	
1 „	vitreous green floor-tile.	
1 „	calcium borate.	

RECIPE FOR SAGE-GREEN GLAZE.

16 lbs.	colourless glaze No. 12.	Grind as No. 1 ivory glaze.
$1\frac{1}{4}$ „	calcined alumina.	
1 „	vitreous green floor-tile.	
1 „	calcium borate.	

RECIPES FOR MALACHITE-GREEN GLAZES.

No. 1.—Malachite-Green Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 ,,	calcined alumina.	
1 ,,	black oxide of copper.	
2 ozs.	common manganese.	

No. 2.—Malachite-Green Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 ,,	calcined alumina.	
2 ,,	stain, as under.	
½ ,,	calcium borate.	

Stain.

16 lbs.	black oxide of copper	ground in water on a potter's colour-pan and dried.
8 ,,	white oxide of zinc	
8 ,,	calcium borate	
3 ,,	alumina, calcined	
2 ,,	frit No. 11	
¼ ,,	black oxide of cobalt	

No. 3.—Malachite-Green Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1½ ,,	calcined alumina.	
2 ,,	stain, as under.	
1 ,,	calcium borate.	

Stain.

12 lbs.	white oxide of zinc.	Calcined in glost oven; and then ground in water on a colour-pan.
6 ,,	black oxide of copper.	
3 ,,	common salt.	

RECIPES FOR WATER-GREEN-TINTED GLAZES.

No. 1.—Water-Green-Tinted Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 ,,	calcined alumina.	
1 ,,	black oxide of copper.	
1 ,,	royal-blue glaze No. 1.	
½ ,,	white oxide of zinc.	
½ ,,	calcium borate.	

No. 2.—Water-Green-Tinted Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
6 ozs.	black oxide of copper.	
2 „	pure hydrate of manganese.	

No. 3.—Water-Green-Tinted Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
½ „	black oxide of copper.	
1 oz.	common manganese ore.	

RECIPES FOR PEA-GREEN-TINTED GLAZES.

No. 1.—Pea-Green-Tinted Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
¼ „	„ ironstone.	
⅛ „	black oxide of copper.	

No. 2.—Pea-Green-Tinted Glaze.

3½ lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
4 ozs.	calcined alumina.	
12 drs.	black oxide of copper.	
8 „	calcined ironstone.	
2 „	common manganese ore.	

No. 3.—Pea-Green-Tinted Glaze.

25½ lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
2½ „	china-clay.	
2¾ „	stain, as under.	

Stain.

16 lbs.	calcined alumina	ground in water in a potter's colour-pan and dried.
3 „	black oxide of copper	
2 „	calcined ironstone	
½ „	common manganese ore	

RECIPES FOR CELADON-TINTED GLAZES.

No. 1.—Light Celadon Glaze.

16	lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
½	„	calcined alumina.	
½	„	stain, as under.	

Stain.

16	lbs.	calcined ironstone	ground in water in a potter's colour-pan and afterwards dried.
6	„	black oxide of copper	
6	„	cryolite	
1	„	cobalt oxide	
1	„	fluor-spar	

No. 2.—Light Celadon Glaze.

16	lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1	„	calcined alumina.	
6	ozs.	stain, as for No. 1 above.	
3	„	calcined ironstone.	
1½	„	common manganese ore.	

RECIPES FOR JADE-TINTED GLAZES.

No. 1.—Light Jade-Tinted Glaze.

16	lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1	„	calcined alumina.	
4	ozs.	„ ironstone.	
2	„	black oxide of copper.	
¼	„	„ „ cobalt.	

No. 2.—Light Jade-Tinted Glaze

16	lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1	„	calcined alumina.	
4	ozs.	stain, as for No. 1 celadon.	
2	„	calcined ironstone.	
1	„	black oxide of copper.	

RECIPE FOR VALLAURIS-TINTED GLAZE.

16	lbs.	colourless glaze No. 1.	Grind as No 1 ivory glaze.
1	„	calcined alumina.	
4	ozs.	„ ironstone.	
2	„	black oxide of copper.	
½	„	„ „ cobalt.	

RECIPE FOR YELLOW-GREEN GLAZE.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
½ „	stain, as for No. 1 old-gold.	
½ „	uranium oxide.	

RECIPES FOR VICTORIA-GREEN GLAZES.

No. 1.—Victoria-Green Glaze.

16 lbs.	colourless frit No. 6.	Grind as No. 1 ivory glaze.
½ „	yellow ironstone.	
½ „	uranium oxide.	
¼ „	black oxide of copper.	
¼ „	white „ „ tin.	

No. 2.—Victoria-Green Glaze.

16 lbs.	colourless glaze No. 4.	Grind as No. 1 ivory glaze.
1 „	U.G. Victoria-green colour.	

RECIPE FOR GREEN-VERDITER GLAZE.

13 lbs.	colourless frit No. 6	Grind as No. 1 ivory glaze.
5 „	white opaque enamel, as under.	
2 „	U.G. Victoria-green colour.	

White Opaque Enamel.

3 lbs.	felspar.	Fritted and ground.
3 „	borax.	
2 „	tin oxide.	
¼ „	common salt.	

RECIPES FOR CELESTE-GREEN GLAZES.

No. 1.—Celeste-Green Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
½ „	U.G. Victoria-green colour	
¼ „	black oxide of copper.	

No. 2.—Celeste-Green Glaze.

16 lbs.	colourless frit No. 4.	Grind as No. 1 ivory glaze.
$\frac{3}{4}$ „	calcined alumina.	
2 „	stain, as for No. 2 malachite-green.	
$\frac{1}{8}$ „	common salt.	

RECIPES FOR CELESTE-BLUE GLAZES.

No. 1.—Celeste-Blue Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
$\frac{1}{2}$ „	stain, as for No. 3 malachite-green.	

No. 2.—Celeste-Blue Glaze (disposed to opalinity).

7 lbs.	colourless frit No. 4.	Grind together.
1 „	stain, as under.	

Stain.

2 lbs.	black oxide of copper.	Grind together.
1 „	zinc oxide.	
1 „	calcium borate.	
$\frac{1}{4}$ „	alumina.	
$\frac{1}{4}$ „	blue glaze, as under.	

Blue Glaze.

5 lbs.	colourless frit No. 11.	Grind together.
$\frac{1}{2}$ „	alumina.	
$\frac{3}{4}$ „	cobalt oxide.	

No. 3.—Celeste-Blue Glaze.

10 lbs. colourless frit No. 6.
1 „ carbonate of copper.

Note.—This requires low temperature and quick cooling.

No. 4.—Celeste-Blue Glaze.

10 lbs. colourless frit No. 16.
5 „ stain, as under.
$1\frac{1}{4}$ „ calcined flint.

Note.—For low temperature and quick cooling.

Stain.

4 lbs.	Cornish china-stone	calcined easily and ground.
$4\frac{1}{4}$ „	ground silica rock	
$1\frac{1}{4}$ „	whitening	
$2\frac{1}{2}$ „	soda-ash	
$\frac{1}{2}$ „	oxide of copper	
$\frac{1}{4}$ „	„ tin	

RECIPES FOR TURQUOISE GLAZES.

No. 1.—Turquoise Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	copper sulphate.	
$\frac{1}{2}$ „	calcium fluoride.	

No. 2.—Turquoise Glaze.

16 lbs.	colourless frit No. 4.	Grind as No. 1 ivory glaze.
$\frac{3}{4}$ „	calcined alumina.	
1 „	copper sulphate.	
$\frac{1}{4}$ „	barium carbonate.	

RECIPES FOR VELVET-GREEN GLAZES.

No. 1.—Velvet-Green Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
$1\frac{1}{4}$ „	calcined alumina.	
$1\frac{1}{4}$ „	black oxide of copper.	
$\frac{1}{4}$ „	common manganese ore.	

No. 2.—Velvet-Green Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
$\frac{1}{2}$ „	uranium oxide, yellow.	
$\frac{3}{4}$ „	copper oxide.	
$\frac{1}{2}$ „	common manganese ore.	

No. 3.—Velvet-Green Glaze

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
2 „	stain, as for No. 2 malachite-green.	
2 „	calcium borate.	

RECIPE FOR PEACOCK-GREEN GLAZE.

No. 1.—Peacock-Green Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
$2\frac{1}{2}$ „	stain, as under.	

Stain.

16 lbs.	black oxide of copper	ground together in water on a potter's colour-pan and afterwards dried.
10 „	colourless frit No. 11	
8 „	white oxide of zinc	
8 „	calcium borate	
4 „	calcined alumina	
$1\frac{1}{2}$ „	black oxide of cobalt	

RECIPES FOR PEACOCK-BLUE GLAZES.

No. 1.—Peacock-Blue Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
$\frac{3}{4}$ „	black oxide of copper.	
$\frac{1}{4}$ „	cobalt oxide.	
$\frac{1}{4}$ „	common salt.	

No. 2.—Peacock-Blue Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
7 ozs.	copper oxide.	
2 „	cobalt oxide.	
4 „	calcium borate.	

No. 3.—Peacock-Blue Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
$\frac{1}{2}$ „	copper oxide.	
$\frac{1}{16}$ „	cobalt oxide.	

RECIPES FOR DARK BLUE GLAZES.

No. 1.—Dark Blue Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze
1 „	calcined alumina.	
1 „	black oxide of copper.	
$\frac{1}{4}$ „	„ „ cobalt.	

No. 2.—Dark Blue Glaze.

16 lbs. colourless glaze No. 1.		Grind as No. 1 ivory glaze.
1 „ calcined alumina.		
$1\frac{1}{8}$ „ black oxide of copper.		
$\frac{1}{4}$ „ „ „ cobalt.		
$\frac{1}{4}$ „ calcium borate.		

RECIPES FOR NAVY-BLUE GLAZES.

No. 1.—Navy-Blue Glaze.

16 lbs. colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „ calcined alumina.	
6 ozs. black oxide of copper.	
2 „ „ „ cobalt.	

No. 2.—Navy-Blue Glaze.

16 lbs. colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „ calcined alumina.	
7 ozs. black oxide of copper.	
2 „ „ „ cobalt.	
1 „ common manganese ore.	

RECIPE FOR OXFORD-BLUE GLAZE.

16 lbs. colourless frit No. 1.	Grind as No. 1 ivory glaze.
2 „ blue vitreous tile pitchers.	
1 „ calcined alumina.	
$\frac{1}{4}$ „ black oxide of cobalt.	
$\frac{1}{4}$ „ common manganese ore.	

RECIPE FOR FRENCH-BLUE GLAZE.

16 lbs. colourless frit No. 1.	Grind as No. 1 ivory glaze.
$1\frac{1}{2}$ „ calcined alumina.	
7 ozs. black oxide of copper.	
$2\frac{1}{4}$ „ „ „ cobalt.	

RECIPES FOR ROYAL-BLUE GLAZES.

No. 1.—Royal-Blue Glaze.

16 lbs. colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „ calcined alumina.	
$\frac{1}{4}$ „ black oxide of cobalt.	

No. 2.—Royal-Blue Glaze.

14 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
$\frac{1}{4}$ „	black oxide of cobalt.	

RECIPES FOR MAZARINE-BLUE GLAZES.

No. 1.—Mazarine-Blue Glaze.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
$\frac{1}{2}$ „	black oxide of cobalt.	

No. 2.—Mazarine-Blue Glaze (a suggestion).

20 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
$1\frac{1}{4}$ „	calcined alumina.	
$\frac{1}{2}$ „	black oxide of cobalt.	
$\frac{1}{2}$ „	whitening.	

RECIPE FOR SKY-BLUE-TINTED GLAZE.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
$\frac{1}{4}$ „	black oxide of copper.	
$\frac{1}{8}$ „	„ „ cobalt.	

RECIPE FOR CAMBRIDGE-BLUE GLAZE.

16 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
$\frac{1}{2}$ „	calcined alumina.	
3 „	vitreous blue tile pitchers.	
$\frac{1}{8}$ „	carbonate of copper.	

RECIPES FOR LIGHT BLUE GLAZES.

No. 1.—Cornflower-Blue Glaze.

16 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
2 ozs.	black oxide of copper.	
1 „	„ „ cobalt.	

No. 2.—Cornflower-Blue Glaze.

16 lbs. colourless frit No. 1.	Grind as No. 1 ivory glaze.
3 „ jasper blue tile-body.	
$\frac{1}{2}$ „ calcined alumina.	

No. 3.—Light Blue Glaze.

16 lbs. colourless frit No. 1.	Grind as No. 1 ivory glaze.
3 „ vitreous blue floor-tile pitchers.	
$\frac{1}{2}$ „ calcined alumina.	

No. 4.—Light Slate-Coloured Glaze.

16 lbs. colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „ calcined alumina.	
4 ozs. „ ironstone.	
1 „ black oxide of copper.	
$\frac{1}{2}$ „ „ „ cobalt.	

RECIPES FOR GREY-TINTED GLAZES.

No. 1.—Celadon-Grey Glaze.

16 lbs. colourless frit No. 1.	Grind as No. 1 ivory glaze.
3 „ vitreous celadon floor-tile pitchers.	
$\frac{1}{2}$ „ calcined alumina.	

No. 2.—Blue-Grey Glaze.

16 lbs. colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „ calcined alumina.	
2 ozs. „ ironstone.	
2 „ common manganese ore.	
1 „ black oxide of copper.	
$\frac{1}{4}$ „ „ „ cobalt.	

No. 3.—Cold-Grey Glaze.

16 lbs. colourless frit No. 1.	Grind as No. 1 ivory glaze.
$1\frac{1}{2}$ „ celadon floor-tile pitchers.	
1 „ calcined alumina.	
2 ozs. „ ironstone.	
2 „ common manganese ore.	

No. 4.—Swanage-Grey Glaze.

22 lbs.	colourless glaze No. 12.	Grind as No. 1 ivory glaze.
$1\frac{1}{2}$ „	calcined alumina.	
4 ozs.	manganese ore (85 per cent.).	
2 „	calcium borate.	
$\frac{1}{2}$ „	black oxide of cobalt.	

No. 5.—Purbeck-Grey Glaze.

15 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
12 ozs.	calcined alumina.	
12 „	vitreous blue tile pitchers	
2 „	manganese ore (85 per cent.).	
$\frac{1}{4}$ „	black oxide of cobalt.	

RECIPES FOR CRIMSON GLAZES.

No. 1.—Crimson Glaze (for muffled-kiln heat).

24 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
3 „	crimson stain, as under.	
$\frac{1}{2}$ „	U.G. claret-brown No. 7.	
$\frac{1}{2}$ „	fluor-spar.	

Stain.

18 lbs.	tin oxide	calcined in china biscuit oven (or to 1200° C.) and ground in water.
8 „	whitening	
3 „	Cornish china-stone	
$\frac{1}{4}$ „	green oxide of chromium	

No. 2.—Crimson Glaze.

20 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
2 „	calcined alumina.	
3 „	crimson stain, as above.	
2 „	fluor-spar.	

No. 3.—Crimson Glaze.

26 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
3 „	crimson stain, as above.	
1 „	calcined alumina.	
$\frac{1}{2}$ „	fluor-spar.	

No. 4.—Crimson Glaze.

24 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 ,,	calcined alumina.	
3 ,,	U.G. printing pink No. 15.	
½ ,,	U.G. claret-brown No. 7.	
½ ,,	fluor-spar.	

RECIPES FOR ROSE-MADDER GLAZES.

No. 1.—Rose-Madder Glaze.

14 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1½ ,,	crimson stain, as for No. 1 crimson glaze.	
1 ,,	fluor-spar.	

No. 2.—Rose-Madder Glaze.

12 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
1¼ ,,	crimson stain, as for No. 1 crimson glaze.	
½ ,,	calcined alumina.	
¼ ,,	fluor-spar.	

RECIPES FOR PINK GLAZES.

No. 1.—Pink Glaze.

32 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
4 ,,	stain "A," as under.	
1 ,,	calcined alumina.	
1 ,,	white oxide of tin.	
1 ,,	stain "B," as under.	
½ ,,	fluor-spur.	

Stain "A."

2 lbs.	felspar.	Calcine in biscuit oven, then grind in water and dry.
1 ,,	Japanese red.	

Stain "B."

14 lbs.	U.G. pink No. 15.	Calcine in glost oven easily, then grind in water and dry.
5 ,,	colourless frit No. 15.	
3 ,,	felspar.	
2 ,,	silica.	
1 ,,	soda-ash.	

No. 2.—Pink Glaze.

24 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
3 „	stain, as under.	
1 „	fluor-spar.	

Stain.

18 lbs.	oxide of tin	calcined and ground.
12 „	Japanese red	
8 „	whitening	
3 „	Cornish stone	
2 ozs.	green oxide of chromium	

No. 3.—Pink Glaze.

32 lbs.	colourless glaze No. 1.	Grind as No. 1 ivory glaze.
1 „	calcined alumina.	
1 „	white oxide of tin.	
1 „	stain "B" of No. 1 pink glaze.	
½ „	fluor-spar.	
½ „	borax.	

No. 4.—Salmon-Pink Glaze.

32 lbs.	colourless frit No. 1.	Grind as No. 1 ivory glaze.
4 „	stain "A" of No. 1 pink glaze.	
1 „	calcined alumina.	
1 „	white oxide of tin.	
½ „	whitening.	

RECIPES FOR COPPER-RED GLAZES.

Mr. W. Burton, F.C.S., at the Society of Arts, said:—"Quite possible to produce copper-red glaze without lead." (*Jour. Soc. Arts*, 22nd February 1901, p. 215.) "The really important part is the production of a glaze which will melt and come perfectly bright and glassy in a reducing atmosphere." (*Ibid.*, p. 216.)

Dr. S. W. Bushell, C.M.G., M.D., has kindly described the method of producing copper-red glazes, as followed by the Chinese, on pp. 139 and 140 of this volume, to which please refer.

RECIPES FOR OPAQUE-WHITE GLAZES.

No. 1.—Opaque-White Glaze.

30 lbs.	ground Cornish china-stone.	Grind together.
15 „	colourless frit No. 14.	
10 „	white oxide of tin.	

No. 2.—Opaque-White Glaze.

20 lbs.	colourless frit No. 13.	Grind together.
$4\frac{1}{2}$ „	ground Cornish china-stone.	
1 „	„ calcined flint.	
1 „	whitening.	
$6\frac{1}{2}$ „	white oxide of antimony.	

RECIPES FOR MATT GLAZES.

No. 1.—Matt or Dull-Surface Glaze.

20 lbs.	colourless frit No. 13.	Grind together.
$4\frac{1}{2}$ „	ground Cornish china-stone.	
1 „	„ calcined flint.	
$4\frac{1}{4}$ „	whitening.	
$3\frac{1}{4}$ „	vitreous white tile-body No. 3.	

No. 2.—Matt or Dull-Surface Glaze.

16 lbs.	colourless glaze No. 12.	Grind together.
8 „	ground Cornish china-stone.	
1 „	calcined magnesia.	

No. 3.—Matt or Dull-Surface Light Primrose-Tinted Glaze.

16 lbs.	colourless glaze No. 12.	Grind together.
4 „	ground steatite.	

No. 4.—Matt or Dull-Surface Golden-Buff-Tinted Glaze.

$10\frac{1}{2}$ lbs.	colourless frit No. 12.	Grind together.
3 „	rutilite.	
$1\frac{1}{2}$ „	ball-clay.	
$\frac{1}{2}$ „	china-stone.	
$\frac{1}{2}$ „	china-clay.	

No. 5.—Matt or Dull-Surface Salmon-Tinted Glaze.

16 lbs.	colourless glaze No. 12.	Grind together.
4 „	stain. as under.	
½ „	calcined alumina.	
¼ „	oxide of tin.	
¼ „	whitening.	
¼ „	calcium borate.	

Stain.

12 lbs.	felspar	calcined biscuit, then ground.
6 „	Japanese red	

CHAPTER XII.

APPLICATION OF THE GLAZES OR ENAMELS.

CONTENTS.—Tile-dipping—Clouding—"Majolica" painting—Glaze-enamelling—Spraying—Drying—Placing—Setting in kiln—Glaze kilns—Firing—Sorting—Shading—Vitreous fresco—Salt-glazing.

(*By permission of Messrs. Ward, Lock, & Co.*)

VERY end is happiness, the glorious consummation of design," wrote Tupper; and as far as each individual tile itself is concerned, the application of the glaze is often a consummation every manufacturer rejoices to see successfully completed.

It has been said that "the glory of a tile is its colour." It may perhaps with equal accuracy be said, "the glory of a tile is its glaze," for in the case of a large proportion of decorative tiles the colour exists within the glaze, not upon nor under it, yet the hue may often be of the choicest. Such coloured glaze or enamel is sometimes flooded over the whole of the tile-face in a single colour or tint, and sometimes several colours are applied upon one and the same tile. But, on the other hand, many useful and beautiful plain tiles, and many artistically underglaze-decorated tiles, are glazed by means of transparent colourless glaze, and these rely either upon the colour of the tile-body, or upon colours applied independently of the glaze, for their chromatic effect.

These and other styles of ornamentation employed necessitate the adoption of different modes of applying the glazes, of which the four principal methods are:—

1. Dipping or partial immersion of the pieces in glaze.
2. Brushing or painting the glazes on.
3. Spraying or blowing the glazes on.
4. Fuming or vapour-glazing.

Tile-Dipping.—Glaze-dipping may be effected either by hand or machine, but at present machines have not made very great headway in competing with the old process of dipping by hand.

The prepared glazes of suitable fineness and consistency, and of the required colour, should be supplied to the tile-dippers in quantities of about half a gallon, and placed in pitchers or enamelled-iron washhand bowls on the work-bench.

The biscuit-tile is taken by the hand, and by an acquired dexterous movement the face of the tile is moved quietly but quickly along the upper stratum

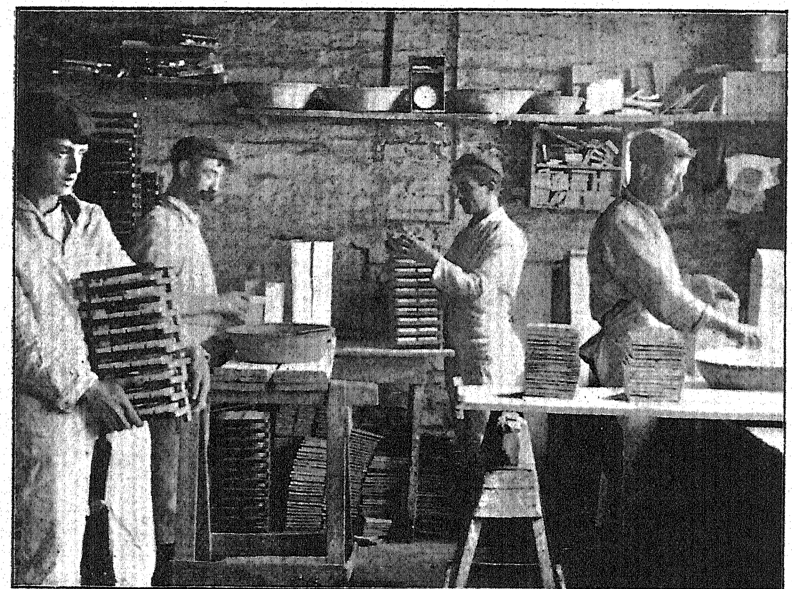


FIG. 275.—Tile-dippers at work. (*Carter & Co.'s "Interesting Notes on Ornamental Tile Manufacture,"* p. 11.)

of the semi-fluid glaze in such a manner as to receive an even coating of glaze on the face only, the water immediately becoming absorbed by the porous biscuit-tile. Sometimes, to secure an extra thickness of glaze deposit on the tiles, they are dipped in the glaze twice in quick succession.

The glaze must be frequently stirred to keep it of even consistence and quality, but air-bubbles must be avoided as much as possible.

By permission of Messrs. Carter & Co., of Poole, Dorset, we are able to illustrate tile-dippers at work (fig. 275).

The coloured glazes may be applied in this manner either to tiles with plain surfaces, or to tiles whose upper surface is ornamented by modelled designs in relief. When embossed tiles are dipped thus in monochrome glaze,

the design is accentuated by the varying depths of glaze forming lights and shades.

Under certain conditions—arising from the nature of the glaze composition, the mode of grinding, the degree of fineness, and the thickness of the coat of glaze applied—semi-fluid glazes, when applied by "dipping," may exhibit a tendency to crack or to lift off the tile during drying. Often glazes subject to these defects will yet lay on the tiles quite satisfactorily if applied by a brush in thin layers, one upon another successively; but, from the record of actual experience in these matters by Mr. Owen Carter (*Trans. A.C.S.*, vol. v. p. 293), it seems that the difficulty, when it occurs, may be overcome by grinding the glaze in the first place in a dry-grinding mill, and subsequently mixing it with sufficient water for dipping, in preference to grinding the frit, etc., by the wet-grinding method so customary in North Staffordshire.

A few of the coloured glazes of which recipes have been given in the preceding chapter are shown on Plate XXXIII. as they would appear when plain-dipped of medium strength.

They have been matched by Messrs. Fleming & Co. fairly accurately, except that the royal-blue and teapot-brown glazes are really very much better colours than the lithographed sheet represents them to be.

Clouding.—Clouded, mottled, or broken colour-effects may be produced by the use of a "clouder" or "dabber," *i.e.*, a piece of wood $\frac{1}{4}$-inch or $\frac{3}{8}$-inch thick, something like the form indicated in the adjoining sketch.

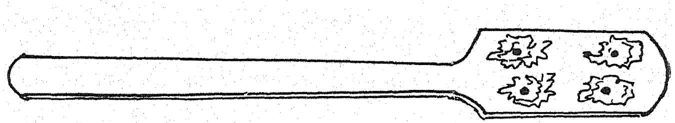


FIG. 276.—Clouder.

To make a "clouder," cut out a piece of wood of the form shown (fig. 276), and tack upon one end loosely some small pieces of sponge, using galvanized-iron or copper tacks.

To use the "clouder," have some coloured glaze of one tint in a creamy condition in a saucer; dip the sponge end of the clouder in clean water, and then into the coloured glaze in the saucer; then with the clouder quickly give the biscuit-tile face three or four dabs with the sponges in different parts, the tile being afterwards dipped in the ordinary way in glaze of another tint. Usually the darker colours are dabbed on and the lighter-coloured glaze dipped on. The processes must follow in quick succession to completion. When a very strong effect is desired, dip the tile first and cloud it afterwards.

Broken Colour Glazes.—Some of the glazes to which this term is now applied appear to be nothing more than partially opalined glazes, such as have given so much trouble to experimenters in easily fusible lead-free glazes.

Dr. Seger met with this opalinity in his researches, and took great trouble

to find means of avoiding it; and glazemakers' current price-lists of to-day furnish evidence that opalinity is still troublesome.

Strange to say, however, this, which has so long been classed as a defect, has recently been elevated into a permissible or even artistic feature, said to be admired by certain buyers, and along with mottled and clouded glazes is now put forward as a decorative novelty.

When, therefore, it is desired to produce this quality in a glaze, it will in many cases be found to be obtainable by displacing the china-clay or alumina, specified to be mechanically added to a frit, by flint or stone. And certain frits, such as No. 4, from which alumina is practically absent, are found to be particularly disposed to yield these opaline results.

"Majolica" Painting or Glaze-Enamelling.—This is a process of brushing or painting different-coloured glazes on different parts of the tile or piece of faience, when a polychrome effect is sought. It may be carried out in several styles—floral, geometrical, blended, *cloisonné*, or a partially glazed surface, after the manner of the enamelled terracotta of Tabriz, mentioned by Halsey Ricardo, in which slabs of terracotta are treated very much as a wood-block, the ground of the pattern being dug away, and the remaining walls, which form the pattern, covered with a turquoise-blue glaze.

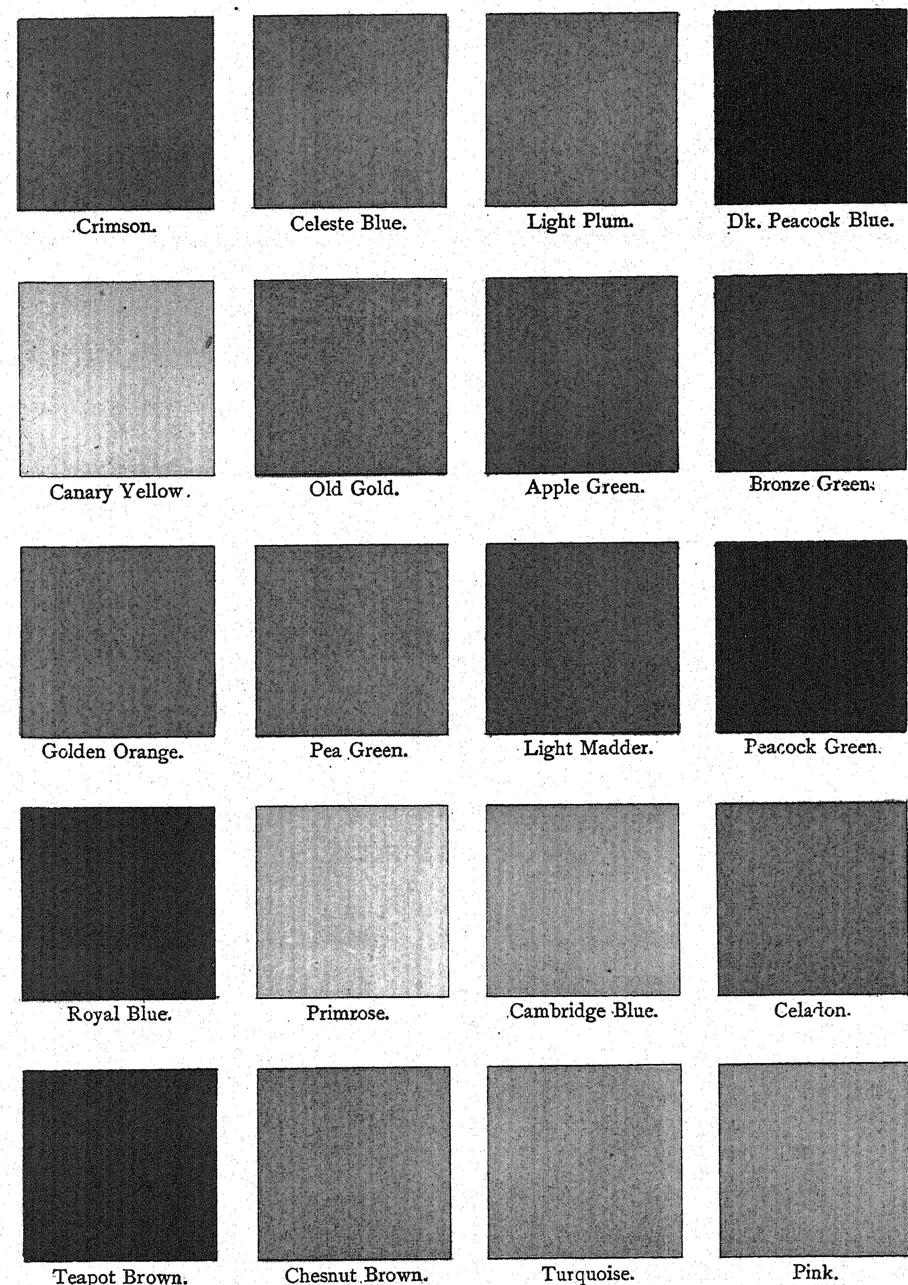
The coloured glazes or art-enamels, as they are often called, are applied by hand-painting of a simple character, usually guided by relief modelling or embossments on the face of the tile or piece of ware. This is usually called "majolica" painting, regardless of the nature of the glazes or enamels, whether transparent or opaque, although in some cases "Palissy" painting would perhaps be a more correct term. When the embossments and colours are appropriately chosen, the product forms a very useful adjunct to plain monochrome glazed-tile work, but considerable judgment is essential to a successful result.

Remarking upon the peculiar success of Hindoo ceramic artists in their colour arrangement, Sir George Birdwood acutely observed that never more than two or three colours are used; and when three colours are used upon the same piece, as a rule two of them are merely lighter and darker shades of the same colour.

The same principle may be observed in some of the most successful polychrome glazed tiles of to-day, and until this elementary but, nevertheless, fundamental and safely-guiding idea has been recognized, we are unable to account for the delight afforded by art-work possessing such sweet simplicity of colouring.

The usual *modus operandi* of majolica-tile painting in North Staffordshire may be briefly described as follows:—The artist having obtained the necessary tiles and coloured glazes, also a pattern or coloured drawing, or verbal instruction, for guidance, applies the coloured glazes mixed with water, in a

PL XXXIII.



Tints of some of the Leadless Art Tile and Faience Glazes and Enamels, of which recipes are given in this volume.

Matched from the Glazed Tiles themselves by Messrs. J. Fleming & Co., Leicester.

semi-fluid condition, to the surface spaces to be decorated, by means of camel-hair pencils, brushes, or sponges, according to the character of the work.

When the painting is complete, the tiles are laid aside upon the bench until they become dry enough to be gathered together in low bungs—back to face—without sticking or pulling glaze off one another, and in this way are carried to the placing-house.

Being usually very porous, the tiles quickly dry the glazes upon their surfaces by absorption. If by chance they have had an excessive biscuit fire and do not dry rapidly, they should be allowed to remain on the bench rather longer before gathering into bungs for removal.

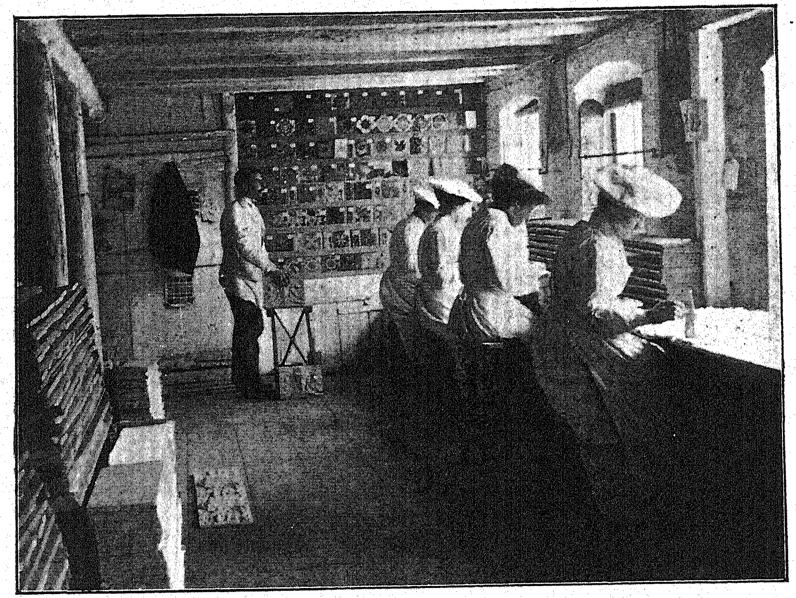


FIG. 277.—Decorating. (*See "Interesting Notes on Ornamental Tile Manufacture,"* p. 13, *Carter & Co., Poole.*)

Blowing on or Spraying the Glaze.—This is a mode of applying semi-fluid glaze in the form of a spray. For very small work, small vapo-bottles are available; but for work on a larger scale, air-compressors, operated by foot-power or steam-power, with suitable vapo-cans, are used (fig. 278). These vapo-cans may be either single cans for one colour of glaze, or triple cans having three compartments, enabling three distinct colours to be blown on at one operation and a marble effect produced.

The method of applying the colour by this apparatus is as follows:—The glazes should first be mixed with water and a little gum-arabic to the consistency of cream and well lawned before being placed in the vapo-can E.

Fill the cans E with the glaze or colour in a liquid state, then by working the pedal A compress the air in drum B.

Either of the various cans may then be directed towards the piece of ware to be glazed, etc., and one of the taps C turned on.

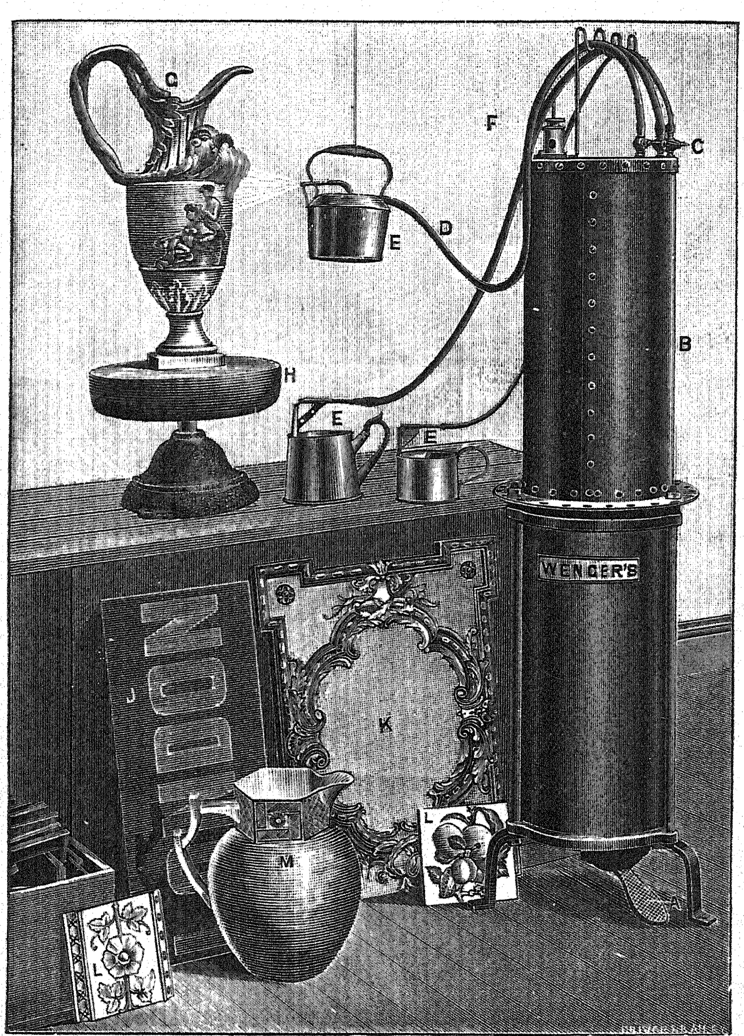


FIG. 278.—Wenger's foot-power air-compressor and vapo-apparatus for glaze-blowing.

In this manner the enamel or slip is thrown in the form of a spray upon the ware G, K, J, M, L, to the desired thickness, at the will of the operator. It is desirable to place a screen behind the ware, to catch any of the liquid that misses the piece under decoration. Very varied effects, particularly

suitable for grate panels, may be secured by this process. For example, the necessary number of tiles to be decorated are set up on a board loosely, and numbered in their respective positions by means of marks in thin glaze on the backs of the tiles. After this the coloured glazes or enamels, ranging from, say, green, blending gradually to a pale yellow, are blown on the face of the tiles in the form of spray, until the whole is glazed.

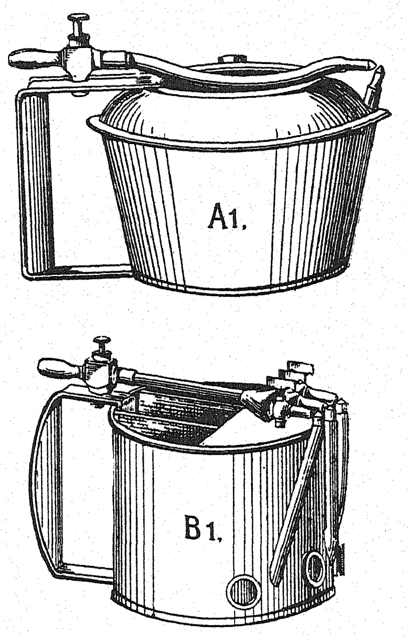


FIG. 279.—Vapo-cans.

After firing, the tiles, being numbered, can easily be placed again in the same order and relative positions they occupied during glazing, and may then be used as required for special decorative effects.

Drying. — Glazing-tiles, being more porous than plastic-made earthenware, usually dry almost as fast as they are dipped in glaze. A work-bench, therefore, with room enough to spread forty or sixty tiles upon will generally suffice for a tile-dipper. For by the time twenty or thirty are dipped, the ware-cleaner can follow and clean excess glaze off the edges, and place the dipped tiles in low bungs preparatory to carrying them to the placing-house.

Dipped tiles must be allowed to become sufficiently dry to prevent them sticking together when gathered into bungs, otherwise they would pull the glaze off each other and cause loss.

At this stage any touching-up necessary to secure the most perfect results should be done.

Placing.—When the glazes have been applied, and after superfluous glaze has been cleaned off the tile edges, the tiles must be placed in suitable fireclay boxes or cranks to support and protect them in the kiln or oven. Bath-tiles and printed tiles, when thinly dipped with rather hard glazes, may be reared vertically face to face and back to back, with suitable separating "thimbles" between each, in saggars, and may be burned in a glost oven. Or they may be placed vertically and directly upon fireclay quarries inside a muffled kiln, in long rows, face to face and back to back, each separated by a thimble-pin; tiers of quarries being fixed inside the kiln by props, so as to carry the rows of tiles one above another. Or they may be placed in the way coloured glazed tiles are placed, as under.

Thickly glazed or art-enamelled tiles, upon which easily fusible glazes

have been applied, require to be burned in a horizontal position, to keep the glaze as evenly spread as possible, otherwise the enamel or glaze would either run off the tile or accumulate heavily along the lower edges. For this reason, "boxes," "cranks," or "setters" are used, mostly about $7\frac{1}{4}$ inches by $7\frac{1}{2}$ inches outside measure, with a clear space inside of about $6\frac{1}{4}$ inches by $6\frac{1}{2}$ inches, upon which tiles are placed. The upper part of the "box," "crank," or "setter" must be brushed over with glaze of some non-colourant kind, so that no biscuit surface may be opposite the glazed face of the tile. When a box has been used for one coloured glaze, it is well to keep it for that or some similar tint so long as it is in use.

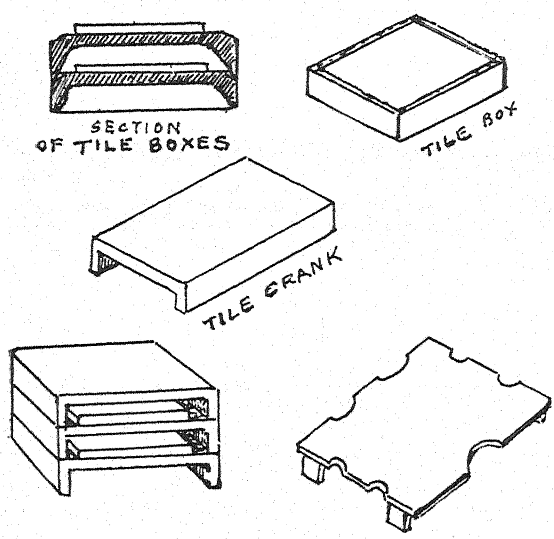


FIG. 280.—Tile-boxes, cranks, and setters.

It will be evident that the very large number of these appliances required encumbers the inside of the kiln with a great mass of unproductive material, which must be heated and cooled each time the kiln is burned; hence the advantage of using setters as thin and small as practicable.

The parts of the boxes, cranks, or setters that will touch upon each other, above or below in the bung or pile, must be brushed with flint slip to prevent adhesion.

The tiles having been placed on the setters or boxes, are then formed in bungs, and may be either put in saggars and fired in a glost oven, or built up in bungs in a muffled kiln for firing.

Pieces of soft-glazed faience, or enamelled terracotta, should be placed in the muffled kiln on fireclay quarries, and all quarries around them in the kiln should be washed with glaze on the sides exposed to the pieces of ware. According to the colour and softness of the glazes, the ware must be placed in different parts of the kiln, those that require or will bear without injury the highest heat being placed in the upper parts; say claret or madder tints near the middle, greens and blues near the bottom, browns and yellows near the top, turquoise in the front part or easiest part of the kiln.

Muffled Kilns.—These are essentially fireclay box-like constructions; the interior box or muffle being formed of fireclay quarries, completely excluding

flames and products of fuel combustion during firing. This is encased with an outer building partly of fireclay brickwork and partly of ordinary building brickwork, terminating in a conical top directing the smoke upwards and permitting the waste gases to escape at a suitable elevation; between the inner and outer structure are fire-mouths, flues, and mid feathers of the necessary construction for guiding the flames and controlling the draught (fig. 281).

An ordinary three-mouth kiln of this character may measure, inside the box or muffle, 7 feet by 6 feet by 3 feet 6 inches, be capable of burning at one time 45 square yards of glazed tiles, occupy from twenty to twenty-two hours in burning; and require about $2\frac{1}{4}$ tons of coal.

Sherwin & Cotton's patent kiln (patent No. 12855, A.D. 1894) has an arrangement by which the fire is conducted round the muffle or box twice instead of once, and is said to be economical and efficient, and largely used.

Such a kiln with four mouths, measuring internally 11 feet by 7 feet by 4 feet, is said to have a capacity of 70 square yards of tiles, and to fire in nineteen hours with 23 cwts. of slack and 7 cwts. of coal.

Firing Glaze Kilns.—In the first place, all cracks and joints in the muffle or interior fireclay-quarry lining of the kiln must be very carefully stopped up with fireclay luting; then the sides and top or interior arch should be washed over with glaze; and it is desirable in some cases, *i.e.*, when the fuel is sulphurous, or the glazes of an easily susceptible nature, to spread lime on the kiln floor or bottom. When the kiln is filled, the front or entrance must be built up with firebricks glazed inside, so as to expose glazed surfaces to the interior of the kiln; and this temporary wall or "clammings" must be 9 inches thick, and thoroughly well luted or stopped up in every part, with the exception of a small aperture or sight-hole, into which a loose brick or a mica window can be inserted. The same kiln may be used for firing both tiles and faience, but it is advantageous to burn the several classes of products at different times. For instance, all tiles dipped in easily fusible glazes may be fired at one time; all plastic-made faience dipped or enamelled with such glazes at another time; and all "harder" or less easily fusible glazed tiles, such as bath-tiles and printed tiles, at another time. In this way the fireman is not worrying about how to accommodate his firing to a multitude of more or less antagonistic conditions, but may devote his attention entirely to one leading set of requirements.

The glazes employed usually mature at about the melting-point of Seger Cones 09 or 07, equivalent to thermoscope bars No. 14 or 16, or Centigrade temperature about 970° C. to 1010° C. (See tables in Chapter V. of this volume.)

Glazed kilns are not "smoked" at the commencement in the manner of biscuit ovens, but are fired right away from the beginning, going slowly only when large pieces of plastic-made faience are in the kiln.

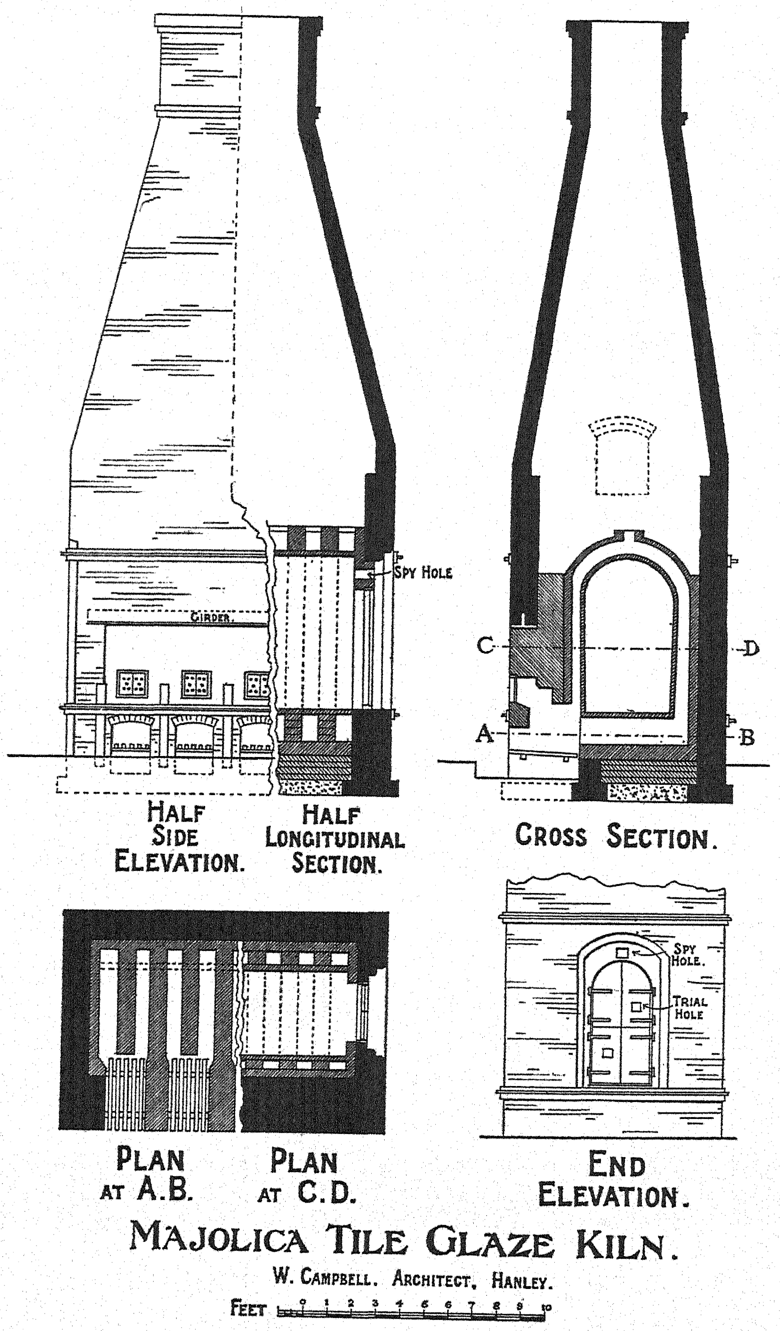


Fig. 281.—Muffled kiln.

In the case of dust-made tiles dipped in easily fusible glazes maturing at about 1000° C. or Seger Cones 07, 08, dull-surface or matt-glazed pieces and certain colours having been placed in the hottest parts, and the other glazes in places most suitable for their perfect development, the kiln may be fired in about twenty hours. For the first twelve hours it is usual to fire with fine small coal or "slack," finishing by five or seven hours' sharp firing with large coal. Immediately the trials show that the heat has been attained, the fires should be drawn out of the fire-mouths, and the kiln allowed to cool down, quickly at first; but it should not be opened and contents withdrawn until two days or, say, twenty-four hours after the firing has been completed. A kiln may be set in, say, on Tuesday, fired during Tuesday night and Wednesday, and drawn on Friday.

In the case of glazes having a tendency to cloud or devitrify, Langenbeck recommends that the wares must be fired and especially cooled rapidly. As soon as the required temperature has been reached, the grate-bars are let down, the fire raked out of the mouths and extinguished. (*Chem. of Pottery*, p. 187.)

In the case of plastic-made faience, although the glazes mature at the same temperature as above, say about 1000° C., the procedure must, nevertheless, be slower and the fires started more gradually, so as to avoid "dunting" or fire-cracking the pieces. In all, about twelve hours' longer time should be allowed in case of kilns in which the greater portion of the contents are large pieces of plastic-made faience.

In the third case, *i.e.*, with "harder" glazes, such as dairy, bath, and printed tiles are usually dipped in, maturing at about 1050° C. or Seger Cone 05, the speed of the fires may be quick, as in the case of majolica tiles; but the temperature required being higher, rather longer time is needed in finishing, and, when the kiln has attained the desired temperature, it should be held at that a little longer.

Glost Ovens.—In general construction these ovens are very similar to those already described and illustrated for burning biscuit-tiles in. And they may either have a protecting hovel, such as that shown with the biscuit oven, Chapter VII., or merely a cone starting close to the oven or kiln, as in the adjoining illustration (fig. 282), drawn by W. Campbell, of Hanley. In the latter case they are generally grouped in a series, and protected in their lower parts by a long continuous shed for the whole series.

Firing Glost Ovens.—The tiles or faience having been enclosed in saggars, and these placed in the most suitable parts of the oven, with trial-pieces in certain saggars, top and bottom, in each quarter, the entrance-wicket or mouth is built up and well luted.

Firing then proceeds quickly from the commencement, no "smoking" being done. The temperature for maturing these glazes is about 950° C. to

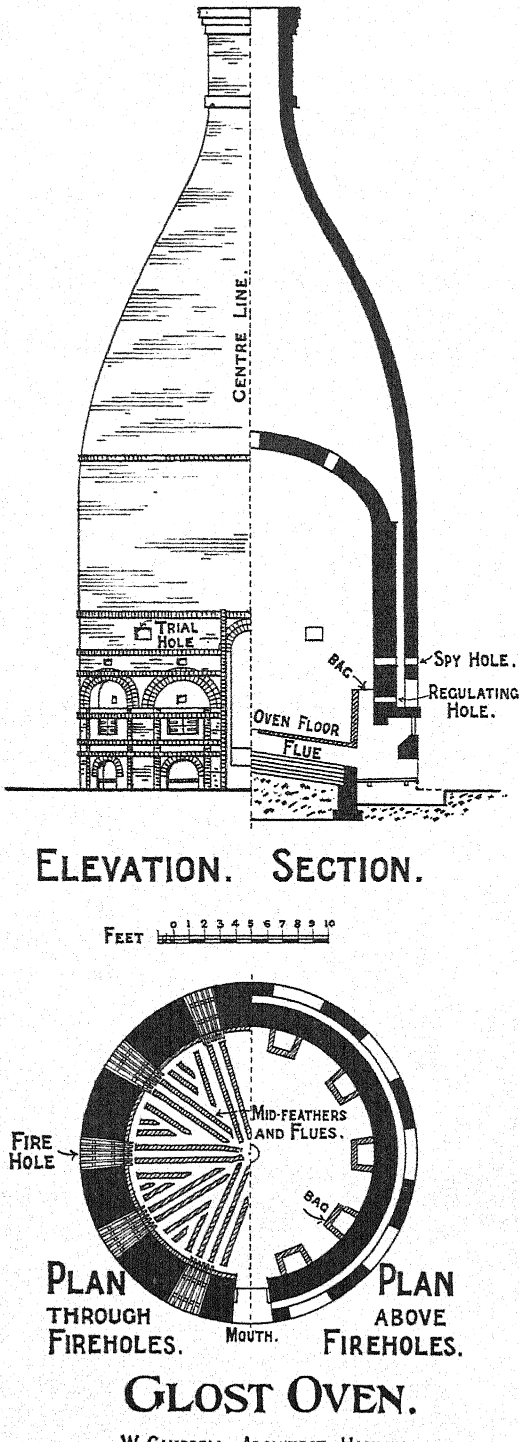


FIG. 282.

1150° C., and this is usually attained in about eighteen or twenty-four hours from start to finish.

The requisite heat having been attained, fires should be drawn and cooling effected as quickly as can be without injury to the ware, particularly in the first two hours or so of cooling.

Referring to the effect of temperature of glost-oven firing on underglaze colours, Mr. Ernest Mayer, of Beaver Falls, Pa., in a communication to the American Ceramic Society, observed that "It is somewhat remarkable that greater progress has not been made by manufacturers of earthenware in the United States in the production of underglaze printed ware . . . . and a careful study of the reason of this may be of interest. . . . . One of the great factors that has a very marked influence on the successful manufacture of this class of ware seems to have been entirely overlooked by the average American manufacturer, viz, the temperature at which English and American glost and biscuit kilns are respectively fired. After a most careful inquiry, I find that the average English glost kiln is fired from 998° to 1036° C., which is equivalent to Seger ·08 to ·06; but mention must here be made that a prominent English manufacturer, who sends the best underglaze printed ware that is imported into this country, assured me that a careful test, made in a thoroughly scientific manner,

showed a heat of only 960° C., equivalent to only Seger ·010 in his glost kilns.

"From my own researches in temperatures in glost kilns in the United States, I have found no one below the heat I have adopted, viz., 1208° C., equivalent to Cone 3, and some run up as high as 1323° C., Cone 7. Now, in a very large measure, this wide difference in temperatures in the two countries—which is over 300° C.—accounts for a very great deal of trouble; but there are also other factors that have to be studied also.

"From actual experience, I have found no trouble in successfully making various shades of brown, green, blue, and black where a suitable glaze is used; and the word *suitable* is used advisedly, because the average glaze, as used by the American potter—at least, as far as those to which I have access are concerned—are not suitable at all." (*Trans. Am. Cer. Soc.*, vol. i.; see also *Pottery Gazette*, December 1900, p. 1369.)

Mr. Mayer then proceeds to discuss the nature of the glazes concerned, and, among other things, asserts that "A high percentage of fritt is a *sine quâ non* for any glaze that will successfully make underglaze printed ware at the temperature to which we go in the United States."

With respect to U.G. pink, for a long time he devoted attention to the composition of the colour, with a view to obtaining the best results; but at last found that the nature of the glaze, next to temperature of glost fire, was really the most important point. In the course of his experiments he found that a glaze of the composition

$$\left.\begin{matrix} 0{\cdot}23K_2O \\ 0{\cdot}77CaO \end{matrix}\right\} 0{\cdot}48Al_2O_3,\ 3{\cdot}90SiO_2,$$

fired in biscuit oven at Seger Cone 9, would either yield pink printed ware, sharp and clear, or pink-tinted glaze when 10 per cent. of U.G. pink was mixed with it.

Mr. Mayer's further notes on the subject are deserving of careful attention by those interested, and will be found in the *Pottery Gazette*, December 1900, or *Trans. Am. Cer. Soc.*, vol. i.

Warehouse Sorting.—If glazed tiles all came out of the ovens or kilns "bests,"—free from nips, chipping, blisters, specks, crazing, peeling, cracking, buckling, dishing, and other undesirable "points"—the tile manufacturer's troubles would end much earlier than they do.

For even after due care has been taken in respect of sorting in the biscuit state, so as to eliminate biscuit "dunted," "nipped," "buckled," or "dished" tiles, there is still a considerable variety of possible defectiveness; so much that classification of these defects may be carried to such an extent in the sorting as to render expedition in "looking out" orders impracticable. This is common experience no more applicable to leadless than to leaded glazes. It is, therefore, more convenient to group defects into some simple classifica-

tions, and perhaps the old sorting into "bests," "seconds," "thirds," and "pitchers" is sufficiently troublesome in practice.

All short-fired tiles and all "split-out" tiles should be swilled with glaze and refired.

Warehouse Shading.—Inequalities of strength of colour upon finished tiles should be avoided as far as practicable, but some variations are inevitable in the process of manufacturing on a large scale, particularly in the thickly dipped soft-glazed tiles usually called "majolica" tiles or art-enamelled tiles.

Precisely similar irregularities may be predicted in the case of leadless glazes and art-enamels, because the thickness of glaze exercises such a determining influence upon the resulting strength of colour. It is scarcely possible to believe how great these differences may be without making tests personally by dipping two tiles in the same glaze, one thickly and one thinly.

This is not a novel phenomena, for long ago Mr. W. Burton, F.C.S., said :—"Beautiful and precious as these coloured glazes are, they are so difficult to keep constant in tint, from the readiness with which they show even slight differences in composition or in firing, that the pottery manufacturer, who feels himself tied down to produce mechanical effects, finds them the most troublesome of all colours to manage." (*Jour. Soc. Arts*, 28th February 1896.) So also Langenbeck, the American expert ceramist, remarks :—"The variations in these can never be prevented altogether, and it is only possible to obliterate the effects of these variations by careful sorting." (*British Clayworker*, July 1899, p. 105.)

It will not be asking too much favour, then, for these newly discovered leadless glazes and art-enamels, if we ask equal care and consideration in shading or sorting into such approximately similar strengths of colour and tint as will accord with the desires of purchasers.

It is not our province to discuss the desirabilty or otherwise of mechanical regularity of tint. Whether such uniformity be dubbed pleasing or the reverse is largely a matter of fashionable ideas among leading artists ; some preferring a lively variety of shades and a diversity of colour, others a rather monotonous, mechanical regularity. The tile manufacturer naturally sinks his own personal likings, and tries to suit and please all buyers.

Vitreous Fresco.—In the Paris Exhibition of 1900 Messrs Doulton & Co., Limited, showed in the interior of their Art Pavilion several art-panels painted by the process they have chosen to designate "vitreous fresco." Forming a band round the greater part of the interior were a set of frieze panels in faience tiles, with a bold treatment of conventional ornament and birds. This band of panels was interrupted on the principal wall by a series of larger paintings in "*vitreous fresco*," painted by Mr. J. H. M'Lennan, from the designs of Mr. A. E. Pearce, assisted by Mr. J. S. Callahan. The side panels were each 5 feet 6 inches long by 4 feet 6 inches high, and the centre panel

8 feet 6 inches by 4 feet 6 inches. The subjects of the cartoons were taken from Malory's "Sir Galahad and the Holy Grail."

Messrs. Doulton & Co. made use of the same process for enriching and adorning the dome in the interior of Birkbeck Bank, Holborn, London, where there are sixteen large panels of this material. "Vitreous fresco" should not, perhaps, be properly classed as glaze-work, and it is only mentioned in this chapter

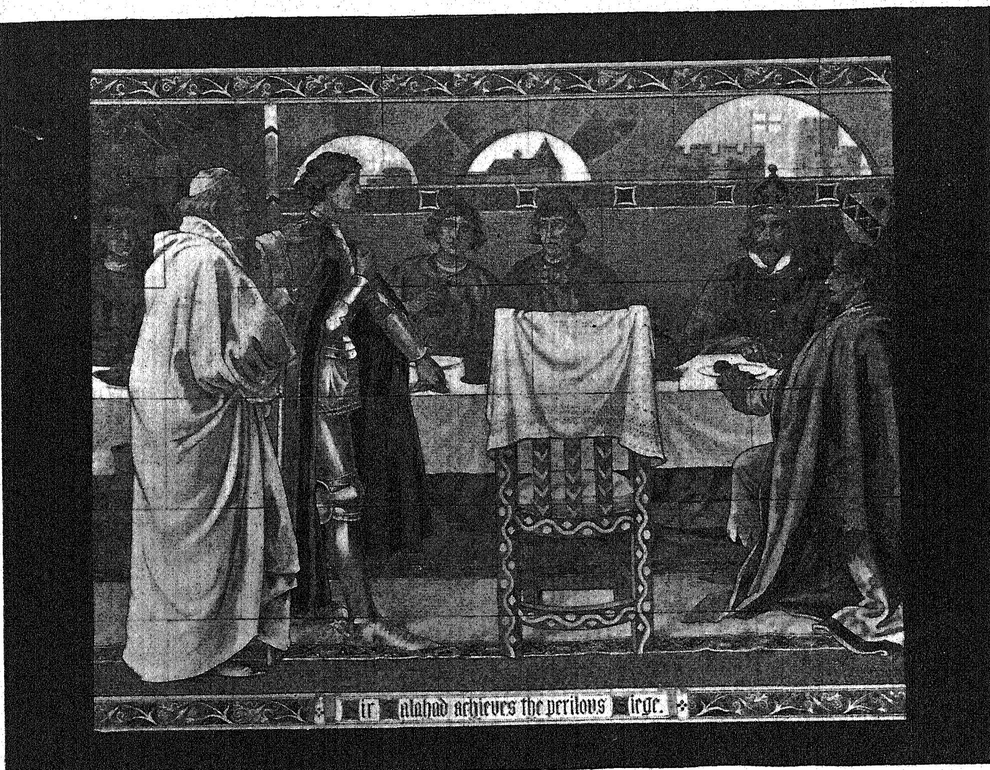


FIG. 283.—Panel in vitreous fresco. (*Doulton & Co., Lambeth.*)

for want of any more suitable position. They consider it a "dry impasto," *i.e.*, impasto-work not glazed, yet of a sufficiently vitreous nature in itself to resist moisture and dust. The colours are painted most artistically upon specially prepared terracotta slabs, and are fired with practically no gloss at all, the work, when finished, having only just sufficient vitrescence for cleaning purposes.

Salt-Glazing.—The use of common salt for glazing pottery is to-day probably as extensive as ever, with the difference that since the eighteenth century, when Burslem town was often plunged in semi-darkness by the smoke and fumes from potters' kilns, the locale and purpose of salt-glazing have shifted.

The beautifully thin, white, and pierced salt-glazed table-wares so delightfully described by M. Solon and Professor Church are commercially no more. The stream of progress has left them aground in museums and collections, interesting merely as souvenirs of the past.

On the other hand, perhaps, never before were so many hundreds of miles of salt-glazed stoneware drain-pipes made, or so many hundreds of tons of salt-glazed chemical apparatus, scullery sinks, traps, grids, troughs, bricks, insulators, ink-bottles, stew-jars, and the like produced. Not only so, for at Lambeth the salt-glazing process has once more been requisitioned in the production of art-wares, and has had a large share of fickle fashion's favours. Of this Mr. Rix tells us that while "nothing could be simpler than the treatment of uncoloured ware . . . . the management of colouring by the 'salt' process is excessively difficult. . . . . The ware is usually fired in an 'open kiln,' that is, exposed to the direct action of the flame; consequently the colours must be able to stand the gaseous impurities emanating from the coal. The number of tints capable of enduring this, and also of resisting the high temperature attained in vitrifying the body, is necessarily limited. The whole process is accomplished in a single firing, and the colours need to be laid with great rapidity, owing to the porosity of the clay. . . . . The violent agitation of the fire-currents, caused by the process of 'salting,' tends to mingle and blend adjacent colours. . . . . The running or weeping of the colours into each other, while in a fluid state, often mars the intended effect. . . . . Salt-glazing, even more than lustre-painting, is a science of probabilities." (*Practical Designing*, p. 88, G. Bell & Sons.)

Salt-glazing is effected by casting common salt into the kiln or furnace through special apertures, at the close of the burning operation, when the kiln is at its highest temperature. In a paper read before the Northern Architectural Association by Mr. W. H. Allen, of Newcastle-on-Tyne, he explains the salt-glazing of drain-pipes as follows:—"When the pipes are what we term 'white' or 'bone-dry,' they are set in the kilns. We have found the best kind of kiln for burning pipes to be the circular kiln. These have fires all around them, so that there is every chance of the whole kiln getting equal heat. The pipes are protected from the flash of the fire by an internal wall running up one or two feet above the fire. The top of the wall all round the kiln is utilised for setting goods on to be burned, excepting the portion directly in front of the fire. These kilns are known as down-draught kilns; the heat ascends to the top of the kiln, but as there is no outlet there, it is drawn by the draught of the chimney down through the pipes and through the bottom of the kiln (the arrangement of which is known as a riddle bottom) to a central well, and thence through underground flues to the chimney. When the kiln is as full as possible, the door-gap is built up, the fires are lighted, and the heat got up very slowly. In the course of three or four days the kiln comes to its

full heat, which is so intense that, looking into it at this stage, you can see every part of the kiln with startling clearness. And now comes one of the most interesting events of all, the process of the manufacture of a pipe, that is, the imparting to it of the brown gloss or glaze with which you are all so familiar in a sanitary pipe. This is done by throwing into the kiln, at almost its greatest stage of heat, a few barrowfuls of common salt. The temperature of the kiln is so high at the 'burning off' that the volatile salt is at once converted into vapour, which completely surrounds all the exposed surface of pipes, etc., in the kiln, and there is consequently a reaction of the vapour on the silica of the clay-bodies. The agent which promotes the action of the silica and common salt is the aqueous vapour which is always present in the flames of the furnace. The oxygen of the water produces soda with the sodium of the common salt, while the hydrogen combines with the chlorine and is evolved as hydrochloric acid. The soda then enters into combination with the silica and forms the glaze. This may be termed a coat of soda-glass; or, in other words, the salt subject to the great heat instantly vaporizes and covers every particle of exposed surface. The first application puts on to the articles in the kiln a preparatory coat of glaze, and successive charges at different periods add to the thickness and lustre of the gloss until sometimes we get what is almost equal to a coat of glass.

"After the last application of salt the kiln is finished as far as the burning is concerned. All air-inlets are closed up, and the kiln is allowed to cool down very carefully. Some idea of the time occupied in this process may be of interest to you, so I will give you a fair average of same. Time of drying on flat, two days; time from lighting the kiln to setting it off full fire (termed soaking), two days; time under full fire, one day; time for cooling, two days." (*British Clayworker*, May 1897, pp. 39 and 40.)

From the very instructive paper read by Mr. W. P. Rix, before the North Staffordshire Ceramic Society, on Salt-Glazing, we learn that the temperature necessary to be attained in salt-glazing kilns is about 1200° C. The chief reason why so high a temperature is required, he tells us, is because as long as the surface of the ware remains porous the soda does not remain upon the surface of the ware, but becomes absorbed in the ware itself; and until the pores immediately below the surface have become filled with alkali, no glazing action takes place upon the surface of the ware.

The salient points he touches upon may briefly be enumerated thus:—The body must be of highly siliceous composition, such as the stoneware clay of Devonshire or finely ground siliceous fireclay. The sand particles present in the body should be fine enough to pass through a sieve of 120-hole mesh. The chemical combination of the alkali with the silica does not readily take place until the point of incipient vitrification of the body has been reached. The surface having been once vitrified, no further change of condition can

take place. The experience required in obtaining uniform results is far greater than in ordinary glost-firing. If the salt is introduced into a reducing atmosphere, the colour of the ware must inevitably be dark, and cannot afterwards be remedied.

The salt should be cast in the kiln in two or three portions at intervals, not altogether; and the draught should be reduced during salting, so as to retard the ingress of cold air, which might rapidly and injuriously lower the temperature of the kiln. Coarse crystals of salt are preferable, so as to secure energetic decrepitation and diffusion. The kilns may, when burning and salting is finished, be rapidly cooled down to about 700° C. or 800° C., after which the cooling process should be comparatively slow.

The quick cooling down from 1200° C. to 700 °C., at the first stage, helps to secure brightness of surface, whilst the slower cooling from 700° C. downwards is necessary to prevent cracking of the ware.

In the Lambeth development, Mr. Rix tells us he covered the surface by pencilling with coloured felspathic glaze infusible at the heat attained, but which fused and developed their colour on the addition of the requisite amount of salt. At the same time he endeavoured to perfect an opposite method based on the principle of using a white Staffordshire fine stoneware body, stained with body-stains, which, by the addition of the salt vapour, was not only glazed, but the colour was further intensified and developed on the surface. He found that the kiln-atmosphere, the correct temperature, and the number of saltings all greatly affected results; and although salt-glazing requires close attention, the variety of effects attainable is practically unlimited. (See *Trans. N.S. Ceramic Soc.*, vol. i. p. 26–32.)

Respecting composition of suitable clay or body, the following analyses are said to represent clays of the best quality for the purpose. (See *British Clayworker*, March and June 1902.)

Silica,	70·50	73·0
Alumina,	24·21	23·0
Oxide of iron,	2·53	1·0
Lime,	0·72	0·5
Magnesia,	0·21	
Alkalies,	1·84	1·5

It is probably incorrect to assume that the silica and soda alone are concerned in the formation of the glaze upon salting. For while it is known that highly aluminous and refractory basic clays do not take salt-glaze well, presumably because of insufficiency of silica, yet silica and soda would not of themselves be likely to yield a durable glaze.

While the silica and soda are in the act of combining, the molten silicate probably incorporates with itself small proportions of lime and alumina from the body-clay, and so forms a glaze that will to a reasonable extent resist solvents.

This side of the subject has been most systematically investigated by Mr. Lawrence E. Barringer, of Schenectady, N.Y., and his results have been recorded and tabulated in a paper read before the American Ceramic Society. (See *Trans. Am. Cer. Soc.*, vol. iv.; also see *British Clayworker*, June and July 1903.)

The paper was entitled "The Relation between the Constitution of a Clay and its Ability to take a good Salt Glaze." He states that "It is a well-known fact that some clays salt-glaze better than others, while some are not at all able to be glazed in this manner. Furthermore, the character of the glaze is different on different clays, as regards colour, hardness, and finish." He describes how he decided to base his tests upon the clay used by the Hocking Clay Manufacturing Co., of Logan, Ohio, whose salt-glazed products are of a high order, consisting of bricks, tiles, sewer-pipes, garden urns, etc. The clay is a fireclay of the Lower Kiltanning horizon, the vein being well weathered.

Careful analyses of the clay yielded an average of

Silica,	63·110
Alumina,	23·300
Ferric oxide,	2·235
Lime,	·725
Magnesia,	·970
Soda,	·490
Potash,	·930
Sulphuric anhydride,	·240
Water,	7·810
	96·810

which he reduced to the following formula :—

$$\left.\begin{matrix}\cdot056\text{CaO}\\ \cdot105\text{MgO}\\ \cdot034\text{Na}_2\text{O}\\ \cdot042\text{K}_2\text{O}\end{matrix}\right\}\left.\begin{matrix}1\cdot00\text{Al}_2\text{O}_3\\ \cdot06\text{Fe}_2\text{O}_3\end{matrix}\right\}4\cdot605\text{SiO}_2(+1\cdot957\text{H}_2\text{O}).$$

The average of two analyses of the glaze was :—

Silica,	55·475
Alumina,	21·340
Ferric oxide,	2·640
Lime,	3·500
Magnesia,	·040
Soda,	17·210
Potash,	·080
	100·285

giving the following chemical formula :—

$$\left.\begin{matrix}\cdot812\text{Na}_2\text{O}\\ \cdot002\text{K}_2\text{O}\\ \cdot182\text{CaO}\\ \cdot002\text{MgO}\end{matrix}\right\}\left.\begin{matrix}\cdot612\text{Al}_2\text{O}_3\\ \cdot048\text{Fe}_2\text{O}_3\end{matrix}\right\}2\cdot704\text{SiO}.$$

$$\overline{\cdot998\text{RO}}$$

Mr. Barringer further shows "the glaze reduced to the same type of formula as the clay, viz., $Al_2O_3 = 1$," which "enables the following comparison to be made :—

$$\text{(Clay)}\quad \left.\begin{array}{l} \cdot056CaO \\ \cdot105MgO \\ \cdot034Na_2O \\ \cdot042K_2O \end{array}\right\} \left.\begin{array}{l} 1\cdot00Al_2O_3 \\ \cdot06Fe_2O_3 \end{array}\right\} 4\cdot605SiO_2,$$

$$\text{(Glaze)}\quad \left.\begin{array}{l} 1\cdot326Na_2O \\ \cdot003K_2O \\ \cdot297CaO \\ \cdot003MgO \end{array}\right\} \left.\begin{array}{l} 1\cdot00\ Al_2O_3 \\ \cdot078Fe_2O_3 \end{array}\right\} 4\cdot418SiO_2.$$

After discussing these formulæ and noting the peculiar higher percentage of lime in the glaze, Barringer continues:—" To throw some light on the relation between the constituents of a clay and its ability to be successfully salt-glazed, two series of experiments were first taken up—one decreasing the ratio of alumina to silica . . . . by additions of sand, the other increasing the ratio of alumina to silica by additions of kaolin. Starting with the Logan clay, unadulterated, systematic additions of sand were made until a ratio of alumina to silica of one to ten had been reached. . . . . For increasing the ratio of alumina to silica the Logan clay was treated with increasing additions of Florida kaolin . . . . ending with trials made wholly of kaolin."

As a result of these tests, he found that a composition of 498 grams of Logan clay with 402 grams of sand (40–60 mesh) received a much brighter glaze than the Logan clay alone, but that the colour of the glazes grew lighter as the sand contents increased. On the other hand, the Logan clay alone is stated to be "uncrazed," while nearly all of those containing added sand are marked "crazed."

Pursuing the sand-adding further, he made a series of tests up to pure sand alone, with the result that the last three tests of this series showed no trace of glaze whatever, and the salt had no action on the pieces.

The tests in which the alumina had been increased deteriorated rapidly until the surfaces became merely a dull red, the kaolin itself showing the appearance of a red-face brick.

The principal conclusions Mr. Barringer draws from his investigations are :—

"(1) A clay may be either too aluminous or too siliceous to be successfully salt-glazed.

"(2) Clays containing alumina and silica between the molecular ratio of 1·00 alumina to 4·6 of silica, and 1·00 alumina to 12·5 of silica, are capable of receiving a salt-glaze if the process is properly carried out. If these limits are exceeded the material is not suited for salt-glazed ware.

"(4) As regards brightness, smoothness, and finish of the salt-glaze, it

makes but little difference whether the free silica in the clay is fine or coarse." (*British Clayworker*, June 1903, p. xxi.)

In a subsequent reference to salt-glazing, Mr. Barringer tells us that the salting temperature of the Logan kilns is 1350° C. or more, while at another works using a shale it is 1140° C. He also comments upon the endothermic reaction by which the kiln is considerably cooled while dissociation of the salt is taking place. (*Trans. A.C.S.*, vol. v. p. 107.)

Respecting this endothermic reaction, Mr. W. Jackson has remarked:—"Besides the loss of heat from the kiln by the inrush of cold air during salting, which was advanced by Mr. Rix to account for the fall in temperature, there was a very large absorption of heat by the chemical changes involved in the glazing operation. The decomposition of the common salt and the water results in the loss of a very large amount of heat. It is true that the re-combination of the alkali with the materials of the body and of the chlorine with hydrogen produce the evolution of heat to a great extent. Yet allowing for this liberation of heat, there is still a net loss of about 120,000 heat units for every 117 grams of common salt vaporised. Some 30,000 heat units are also required to raise the vapour to the temperature of the kiln when salting. Hence there is a total net loss of about 150,000 units during the vaporising of the given amount of salt."

The wandering of colour during the salting process Mr. Jackson attributes to the formation of volatile chlorides of the colourant oxides. (*Trans. N.S.C.S.*, vol. i. p. 34.)

The quality of salt most suitable is said to be coarse, large crystal-salt, such as is used for pickling; and the quantity about 60 lbs. to 70 lbs. per 1000 bricks or sewer-pipe in the kilns.

CHAPTER XIII.

ON-GLAZE DECORATIVE PROCESSES.

CONTENTS.—Emery-wheel etching—Sandblast—Enamel-colour painting—Glost-printing—Litho-transfers—Aerographing—Lustres—Copper-ruby glaze—English lustres.

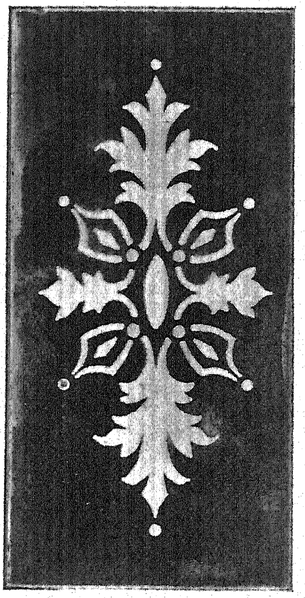


FIG. 284.—Sandblast-decorated glazed tile.

APART from lustre enrichments, on-glaze ornamentation of tiles is perhaps the exception rather than the rule. Increased cost and lessened durability are things to be studiously avoided in structural ceramics, hence for these and other reasons this section of the art is but sparsely represented in the decorative-tile trade. A very few notes, therefore, upon the usual on-glaze processes, and a *résumé* of the history and *technique* of lustre decoration, will cover all that is needed in these respects.

Etching.—Exception may be taken to the classification of etching as an on-glaze process; but without quarrelling about trifles, it will be enough for our purpose merely to mention the several common methods. The glass-grinder's wheel and emery may be effectively employed by skilful operatives, and yields chaste, unobtrusive, yet artistic effects. In the case of richly coloured glazes on pale cream-coloured bodies, thinning of the coat of glaze in any part and to varying depths develops powerful lights and shades, and thus the process has considerable possibilities.

When, however, an even depth of etching, slight or otherwise, is required, beautiful designs may be etched in the glazed surface by sandblasting.

A pattern cut on a tile by the Lancashire Sandblast Co., of Manchester, is represented by fig. 284.

The writer is not aware to what extent either the above or the hydrofluoric acid processes are employed in the tile trade; but Mr. W. Burton has stated that many pieces of dull glaze produced by such methods were shown in the Paris Exhibition. (*Jour. Soc. Arts*, 22nd February 1901, p. 217.)

Etching is extensively and effectively employed in the decoration of glasswares, and its occasional use in tilework seems quite admissible.

"On-Glaze" or Enamel-Colour Painting.—The possibilities of increased minutiæ of detail and greater refinement and delicacy of colour attainable by the use of on-glaze enamel colours are not a sufficient advantage for the purposes of structural embellishment to warrant the increased risks and costs entailed, and to compensate for a somewhat lessened degree of permanence of the work. Indeed, apart from questions of cost and durability, it is possible to overload a tile with exquisitely beautiful ornamental details so minute as to be totally lost in decorative effect, and may even create an objectionable blur or misty indistinctness when viewed, as decorative work must often be, from a distance of several yards.

Let a piece of enamelled and gilt Satsuma ware, with its microscopic detail of decoration, be placed on a shelf alongside a mediæval Damascus painted tile, and let them be viewed from a distance of two or three yards; the decorative futility of the one and the decorative power and aggressiveness of the other will immediately be apparent.

Sir W. B. Richmond discovered a similar fact when his earlier mosaics were fixed *in situ* in St. Paul's Cathedral, for he has confessed that he made too many details, and had, in fact, put in too much work. On the other hand, he says the influence of detail is never wholly lost, and, although it may be overdone, it is worse to underdo it.

Appropriateness is always an essential consideration in any decorative scheme. What may suit a small room or vestibule may be too indefinite for a large public building; but, apart from that view, there are some who, as a pure matter of merit, have a distinct partiality for underglaze work. Dr. J. W. Glaisher, F.R.S., when addressing the Society of Arts, expressed himself thus:—"For my own part, I cannot bring myself to feel any satisfaction in painting executed upon the glaze. The surface is hard, and there is no intimate connection between the painting and the manufactured ware to which it is attached. The colours are fired at a much lower temperature than that required to produce the piece; in fact, only just so much heat is applied as will make them adhere to the glaze." (*Jour. Soc. Arts*, 11th June 1897, p. 667.) And Mr. W. Burton has said:—"Certainly no one who understands and fully appreciates pottery colour is likely to rank the finest triumphs of on-glaze work with the simpler, but richer, effects of underglaze colour or coloured glazes." (*Jour. Soc. Arts*, 28th February 1896, p. 329.)

When for any special purpose on-glaze colour decoration is desirable,

the process may be that usually adopted in ordinary earthenware enamel on-glaze painting, which, briefly, is as follows:—The colours must be of an easily vitreous nature, melting down firmly on the glaze at temperatures between 600° C. and 800° C. for ordinary enamel-kiln colours, or between 830° C. and 950° C. for hard-kiln colours, and must yield a glassy enamel (unless otherwise desired) adhering firmly to the glaze of earthenware. Some enamel colours are found to be specially suitable for earthenware decoration, while others suit bone chinaware better; the tile decorator's selections of enamel colours must therefore be judiciously made.

The glazed surface of the tile or piece of ware to be decorated should be wiped clean and freed from grease-marks or perspiration. Then the design should be mapped out. If the ware is of light colour, the mapping-out may be done with Indian ink; but if of dark colour, map out the design by means of water-colour, buff, or vermilion.

Then take some of the finely levigated vitreous colour of the required shade, and dry it. Then place a small portion of the dried ground colour on the palette or slab, add a little turpentine, and grind them together thoroughly by means of a flat-faced muller, thinning occasionally by adding turpentine as necessary. When well ground, dry again. Afterwards add "fat oil," and mix together on the slab or palette, care being taken that the mixture of colour and medium is not thinner than syrup.

When painting, use a little turpentine with the pencil, but only sufficient to give the desired strength of colour. Do not apply one colour upon another until the first one is quite dry and set. When using white enamel, rub up the colour with a bone knife, not the ordinary steel palette-knife.

After completing the painting, let the work set hard and dry, and then burn in enamel kiln (600° C.–800° C.), or in the hard kiln (830° C.–950° C.), according to the colour used.

Dark blues, not of a very vitreous character, are often applied in the manner just described, and burned in the enamel kiln, when they come out dull black; the ware is then burned again in a glost oven at about 1070° C., which develops the colour by melting it into the glaze. This is called oven-blue colour. Several other colours may be treated in the same way.

Glost-Printing.—Enamel-printing, or printing vitreous colours on the fired glazed ware, may be effected thus:—Apply a thin coating of size to the glazed surface by rubbing it on with cotton wool. The size is a special composition known to pottery printers, a recipe for which may be found in Corfield's recipes. After the pieces have been thus prepared, they must be allowed to rest half an hour. Printing may then be proceeded with in the manner already described in a previous chapter, except that, as Professor Binns points out, the engraving in the copper-plate must not be so deeply cut as for biscuit-printing. (*Story of the Potter*, p. 224, Newnes.)

When printed, the ware or tiles should be set aside, with the transfer-paper adhering to them, until next day; then the tissue-paper may be removed by means of a damp sponge. The ware must then be burned in the enamel kiln (a small muffled kiln, the heat of which does not usually exceed 830° C.).

This glost-printing may either be used as a complete decoration or as a pattern for subsequent "filling-up" with other colours by hand.

Leadless enamel colours are now obtainable by those who desire them. A range of these, applied to chinaware partly by printing, partly by hand-painting, and partly by oil and dusting, have been soaked in water continuously for more than twelve months, the water being renewed occasionally to make up for evaporation. At the end of the period the pieces were all soaked in warm water and thoroughly scrubbed twice; yet not a single trial on any of the thirteen pieces of enamel colours which had been passed for use showed any sign whatever of being injured or affected in any way by the long soaking. It has been asserted that leadless-enamel on-glaze colours easily wear off, but the foregoing distinctly refutes the charge; whereas lead enamels admittedly wear off. Mr. W. Burton has told us that "At the easy or ordinary kiln heat the colour becomes merely attached to the glaze, without sinking into it appreciably; frequently it is dryer, and not so glossy of surface as the glaze, and it is often so imperfectly vitrified as to wear off under ordinary domestic usage, so that dinner-plates and similar articles decorated with ordinary on-glaze colours and gold will show signs of wear after a few years of use. The on-glaze colours fired through the hard kiln are not generally faulty in this respect." (*Jour. Soc. Arts*, 28th February 1896, p. 328.) That, of course, refers to lead-enamel colours applied upon lead glazes. If similar defects arise with leadless-enamel colours, what cause need there be for greater complaint of one than of the other?

Tile decorators may in passing lay to heart the determination to use only hard-kiln enamel colours for tiles, and thus secure so much of permanence as the process permits.

Enamel litho-transfers undoubtedly are eligible to a similar extent for tiles, as also enamel-colour aerographing; all, of course, with the limitations and drawbacks already referred to.

Lustre.—"*Who shall . . . : analyse the jewelled lights that deck the peacock's train? or shrewdly mix upon a palette the tints of an iridescent spar?*" (Tupper.)

Whatever may be the powers of savants in other realms of art, the ceramist, at least, is now able to mix cunningly devised compounds which yield beautiful iridescent effects when applied to his wares. And even though these are inferior to the enchanting scintillations of "fire opal," or the lovely steel-blue sheen of polished chameleon-stone, or the rainbow tints of the Australian letter-stone, this addition to a potter's resources helps him to attain pleasing

diversity in his products, and compete with other materials for the favour of the wealthy.

Tupper, with all his wisdom, evidently overlooked the fact that long ago Persian, Saracen, Moresco, and Italian had shrewdly mixed an iridescence-forming compound; and that as early as A.D. 1040 in Cairo, and from 1154 A.D. onward in Spain, lustred wares had been made, the most notable centres being Calatayud in Andalusia, Malaga in Granada, Manises in Valencia, Muel in Aragon, and somewhere in the Isle of Majorca.

Señor Juan Riaño furnishes a very interesting description of how the process was carried on at Muel, which is of sufficient interest to repeat at length:—"At Muel, a village in the province of Aragon, near Zaragoza, this industry existed to a great extent in 1585. In the travels of Henrique Cock . . . . we find the following interesting details of the manner in which this pottery was made: 'Almost all the inhabitants of this village are potters, and all the earthenware sold at Zaragoza is manufactured in the following manner. First the vessels are fashioned of a certain ingredient the earth furnishes them in that locality, in the shape they may require. Once made, they bake them in an oven fitted for the purpose. They then remove them to varnish with white varnish and polish them, and afterwards make a wash of certain materials in the following manner: 25 lbs., *one arroba*, of lead, with which they mix 3 or 4 lbs. of tin, and as many lbs. of a certain sand which is to be found there. All these ingredients are mixed into a paste like ice; it is broken into small pieces, and pounded like flour, and kept by them in powder. This powder is mixed with water, the dishes are passed through it, and they are rebaked in the oven and keep their lustre. Afterwards, in order that the pottery may be gilt, they take very strong vinegar, mixed with about two reales (a small coin equivalent to 6d.) of silver in powder, vermilion, and red ochre, and a little wire. When all is mixed together, they paint with a feather on the dishes any decoration they may like, rebake them, and then they remain gold-coloured for ever. This was told me by the potters themselves.'" (*Spanish Arts*, p. 150, Chapman & Hall.)

But Senor Riaño, in the next paragraph, becomes even more interesting. He writes:—"But nothing can be compared in exactitude to the following receipt of the manner of preparing this lustred ware, which I was fortunate enough to find in a manuscript in the British Museum (Egerton, No. 507 MS., fol. 102). Count Florida Blanca, wishing in 1785 to establish at Madrid a manufactory of metallic-lustred ware, had the following report on the actual state of the industry sent to him from Manises, with full details of the manner in which it was required to be carried out. 'After the pottery is baked, it is varnished with white and blue, the only colours used besides the gold lustre: the vessels are again baked; if the objects are to be painted with gold colour, this can only be put on the white varnish after they have gone twice through

the oven. The vessels are then painted with the said gold colour, and are baked a third time, with only dry rosemary for fuel. The white varnish used is composed of lead and tin, which are melted together in an oven made on purpose. After these materials are sufficiently melted, they become like earth, and when in this state the mixture is removed and mixed with an equal quantity of weight in sand; fine salt is added to it, it is boiled again, and, when cold, pounded into powder. The only sand which can be used is from a cave at Benalguacil, three leagues from Manises. In order that the varnish should be fine, for every *arroba*, 25 lbs. of lead, 6 to 12 ozs. of tin must be added, and half a bushel of fine powdered salt; if a coarse kind is required, it is sufficient to add a very small quantity of tin, and 3 or 4 cuartos-worth of salt, which in this case must be added when the ingredient is ready for varnishing the vessel.

"'Five ingredients enter into the composition of the gold colour: copper, which is better the older it is; silver, as old as possible; sulphur, red ochre, and strong vinegar, which are mixed in the following proportions: of copper, 3 ozs.; of red ochre, 12 ozs.; of silver, 1 *peseta* (about a shilling); sulphur, 3 ozs.; vinegar, a quart. Three lbs. (of 12 ozs.) of the earth or scoriæ, which is left after this pottery is painted with the gold colour, is added to the other ingredients.

"'They are mixed in the following manner:—A small portion of sulphur in powder is put into a casserole with two small bits of copper; between them a coin of silver *peseta*: the rest of the sulphur and copper is then added to it. When this casserole is ready, it is placed on the fire, and is made to boil until the sulphur is consumed, which is evident when no flame issues from it. The preparation is then taken from the fire, and when cold is pounded very fine: the red ochre and scoriæ are then added to it; it is mixed up by hand, and again pounded into powder. The preparation is placed in a basin and mixed with enough water to make a sufficient paste to stick on the sides of the basin: the mixture is then rubbed on the vessel with a stick; it is therefore indispensable that the water should be added very gradually until the mixture is in the proper state.

"'The basin, ready prepared, must be placed in an oven for six hours. At Manises it is customary to do so when the vessels of common pottery are baked: after this the mixture is scratched off the sides of the basin with some iron instrument; it is then removed from there and broken up into small pieces, which are pounded fine in a hand-mortar with the quantity of vinegar already mentioned, and after having been well ground and pounded together for two hours the mixture is ready for decorating. It is well to observe that the quantity of varnish and gold-coloured mixture which is required for every object can only be ascertained by practice.'" (*Spanish Arts*, p. 151.)

In Persia the art of lustre was lost apparently about A.D. 1665; and with

regard to Italy Wm. De Morgan said:—"All lustres disappear from Italian decorative work about 1550, so that a period of sixty years covers the whole production." Hispano-Moresque lustres had a rather longer lifetime, but eventually ceased to be used on elaborate work; and if not completely, they practically ceased to be exercised to any noticeable extent.

"Whatever the cause," said De Morgan, "or complication of causes, they vanish in 1550, and do not reappear for three hundred years. The process is not described by Brongniart, who was the great technical authority on pottery of fifty years ago; and Salvétat, who was his successor, makes only a very speculative allusion to its possible character. And in the catalogue of the Great Exhibition of 1851, which is a sort of death register of the arts of antiquity, not a hint of lustred pottery appears." (*Jour. Soc. Arts*, 24th June 1902.)

Some kind of lustre-ware would, nevertheless, appear to have been made at Brislington in the eighteenth century. A description of this is given on p. 139 of the *Handbook to the Pottery and Porcelain in the Museum of Practical Geology, Jermyn Street, London, 1893.* The body was said to be hard and coarse, composed of clay and sand, and covered with a yellow enamel dip, over which a brilliant copper lustre composed the decoration, probably copied from Hispano-Moresque. The manufacture is said to have been carried on at Brislington by Richard Frank, but became extinct before the end of the eighteenth century.

Mr. Burton states that "The process still survived in some of the small potteries in Spain, where it had been handed down from father to son; but these potters were out of touch with the rest of Europe, and the revival of true lustres at Gubbio and Doccia, and later by Mr. De Morgan in this country, owed nothing to tradition, but were genuine rediscoveries of a process overlooked or forgotten for three hundred years." (*Jour. Soc. Arts*, 22nd February 1901, p. 214.)

Marryat, on p. 458 of his *Pottery and Porcelain*, tells that Professor Bonfatti, of Gubbio, had written to Mr. Layard that a young man named Luigi Parocci, a pupil of the chemist Professor Angelico Fabri, had recently discovered the manner of producing the celebrated varnish of Maestro Giorgio, and of applying it not only to the reds but to other more rare tints; and that at an exhibition twenty plates so treated were shown, and were taken for ancient ware by those who saw them. This note is dated by Marryat, 1857.

Respecting the modern revival of lustre decoration, Wm. De Morgan said:—"The modern revivals begin with those at the Ginori factory at Doccia near Florence, and those of Carocci at Gubbio, of which Mr. Fortnum speaks very highly. There were some of these in the 1862 Exhibition in London. . . . . The best I have seen are those of Cantagalli at Florence.

"In spite of the Doccia and Gubbio reproductions, an impression con-

tinued to prevail that the process was a secret. I used to hear it talked about among artists, about twenty-five years ago, as a sort of potters' philosopher's stone. . . . . My attention was attracted to some very interesting work of Massier, of Cannes, in the last Paris Exhibition, by a newspaper paragraph headed 'Rediscovery of a Lost Art.' In fact, rediscovery appears to have dogged the footsteps of the lustres from the beginning. I rediscovered them myself in 1874 or thereabout, and in course of time some of my *employés* left me and rediscovered them again somewhere else. I do not think any rediscoveries of this sort contributed in any way to the very general diffusion of the process in the potteries at this moment. Very likely some of them have an earlier record than mine, but the only one I chanced upon when I was in Staffordshire was that of the late Mr. Clement Wedgwood, who showed me a number of experiments which would have been successful if the glaze had been suitable, and a small sample shown me by the late Mr. Colin Campbell. . . . .

"Perhaps we may now make a new departure, and consider that the process is as well known as any other process in the arts; at anyrate I will contribute what I can to make it so, by telling all I know of it myself.

"I got nothing from Piccolpasso, as I did not see the work till long after; nor from any printed information, except the chemical manuals I had read in youth. The clue was furnished by the yellow stain of silver on glass. When overfired this showed iridescence, which is often visible on the opaque yellow visible from the outside on stained-glass windows. I tried the stain on Dutch tiles, and found them unsusceptible in the glass kiln, but in a small gas muffle I found that both copper and silver gave a lustre when the gas was damped down so as to penetrate the muffle. I pursued my investigation, and after an interruption, occasioned by setting the house on fire and burning the roof off, I developed the process in Chelsea. This was 1873–1874, since which time it has not varied materially, although I have tried many experiments with a view to improving it.

"As we now practice it at Fulham, it is as follows:—The pigment consists simply of white clay, mixed with copper scale or oxide of silver, in proportions varying according to the strength of colour we desire to get. It is painted on the already fused glaze with water, and enough gum-arabic to harden it for handling and make it work easily—a little lamp-black or other colouring matter makes it pleasanter to work with. I have tried many additions to this pigment . . . . but without superseding the first simple mixture. Any infusible clay will answer the purpose, though we have always used kaolin. . . . .

"The ware, when painted, is packed in a close muffle, which is then raised to a very low red heat, so low, when the ordinary tin enamels are employed, as to be only just visible. A charge of dry wood, sawdust, wood-chips, or,

indeed, any combustible free from sulphur, is then introduced into the muffle through an opening level with the floor, a space having been left clear under the ware for its reception. As soon as it has blazed well up, the opening is closed. The flare then chokes down, and the combustion of the charge is retarded, the atmosphere in the muffle consisting entirely of reducing smoke. The test-pieces will soon begin to show a red or yellow stain, the pigment itself looking black, until it is wiped off to show the stain. This operation must be repeated until the tests look right, when the fires should be drawn and the muffle left to cool. . . . .

"The firing may be vitiated . . . . by any of the following causes. There may be too great heat or too prolonged heat; the smoke may be too dense or too attenuated, or not long enough maintained, or the reverse. . . . . Even when the conditions are most closely observed, the results will show unexpected variations. It is impossible to secure uniformity throughout a muffle. Consequently the size of the ware must be small in proportion to that of the muffle, or a vase might be overdone at the top and underdone at the bottom. . . . .

"I have said that the tin glaze is the most suspectible to lustre, but it does not necessarily give the finest results. The Gubbio lustres are really on superposed marzacotta, and possibly the exceptional beauty of some Persian lustre may be due to what is often called a siliceous glaze, which is what I called an alkaline glaze, as all glazes are siliceous. . . . .

"The best of the first lustres I made on Staffordshire ware were on *ironstone* or *granite*. The body was repellent in colour, but the glaze particularly good. Latterly, we have used the common opaque white made with tin. It has also been ugly in colour, being, I believe, made so by the addition of cobalt, to make it whiter. . . . . I have tried many experiments with glazes, but I am inclined to think that the way they are fired in the glost oven has as much to do with their adaptability for lustre as their chemical composition.

"I have also tried in this past twenty years a vast number of experiments, with the idea of adding to the first simple process of the Arabs. To save others needless work, I will enumerate a few, with my recollection of their results.

"(1) Reduction by other agents than carbonaceous smoke: by ammonia, by steam in contact with reducing fuel, by coal-gas, by vapour of water and glycerine or spirit. None of these gave any new results.

"(2) The use of copper and silver colours as enamels, or underglaze, and their subsequent reduction by any of these agents. Sometimes there were good results, but the colour was always patchy.

"(3) The deposit of copper or silver from vapour of the chlorides, ammonium chlorides, or iodides, those portions of the glaze being protected which were to remain white. These experiments might be repeated with advantage. A

similar one was the painting of the pattern in a susceptible glaze on a refractory one, and its exposure to vapour containing copper or silver. The suboxide of copper itself vaporises under certain conditions, which is the cause of the flown red colour occurring on many examples.

"I have, of course, tried endless modifications of the ordinary process, such as using special woods for smoking, sawdust, shavings, paraffin, and other combustibles. Any of these answer the purpose, the application being slightly varied. But nothing material has come of any of these experiments, and the process remains substantially the same as at first." (*Jour. Soc. Arts*, 24th June 1892.)

Mr. William De Morgan courted publicity for his most instructive paper, and the editor of the *Journal of the Society of Arts* kindly granted permission for the above excerpt.

We therefore feel personally indebted to each of the learned and courteous gentlemen concerned, and we feel unable to find more suitable terms in which to express this sense of obligation than those used by Mr. Forbes Robertson in his highly complimentary remarks during the discussion upon Mr. William De Morgan's paper:—"Mr. De Morgan might be assured that he had devoted himself to the most enduring of all arts. Everything done by the hand of man in stone or metal would one day disappear; but thousands of years hence his little articles of pottery, however fragmentary, would remain. When all the other things which marked the state of civilization at any particular period had gone, and when the names of all our living academicians were forgotten, bits of Mr. De Morgan's pottery would be found, and mentioned with respect."

A very concrete and yet varied series of recipes and directions for the preparation of ceramic lustres appeared in *The Artist* of November 1899. These recipes, however, are so largely dependent upon chemical and physical compounds of lead associated with the use of carbolic acid as a medium and reducing agent, that they are unsuitable for mention in this publication.

They probably furnish no artistic effect that may not be obtained with equal success and far less risk by other means.

Indeed, as we have seen, Mr. W. De Morgan expressly attributed the exceptional beauty of some Persian lustre to the fact that it is applied upon a silico-alkaline glaze.

The one thing that De Morgan considers of greatest importance is the presence of tin in the glaze or enamel upon which the lustre composition is placed. To repeat his own words:—"Now I can testify, and so can every potter who has ever made lustre, to the facility and certainty with which it can be produced when tin is present in the glaze as compared with other glazes." (*Jour. Soc. Arts*, 24th June 1892, p. 760.) At the same time he has said:—"The harder the glaze and the higher the temperature, the less likely is a deposit of metallic copper." (*Ibid.*, p. 763.)

Copper-Red Glaze.—This appears to be something of the nature of a sequel to copper lustre. De Morgan speaks of it as a result of prolonging the heat without smoke. "The deposited copper is thus slowly absorbed in the glaze, becoming ultimately red without lustre, but passing through every intermediate stage." (*Jour. Soc. Arts*, 24.6.1892, p. 763.)

Mr. W. Burton speaks of it as also obtainable by putting copper oxide into the glaze mixture before it is fired, and when the glaze is melted on the ware in the kiln it must be surrounded by reducing gases. "Roughly speaking," he continues, "*rouge flambé* glaze differs only from copper-red stain by the method and temperature of its production. I have pointed out that the temperature at which lustre is produced is very low, in fact, a just visible red heat; but the temperature needed in the case of copper-red glaze is that at which the glaze itself will melt and mature. Again, while it seems very difficult, if not impossible, to produce copper lustre on a leadless glaze, it is quite possible to produce copper-red glaze without lead." (*Jour. Soc. Arts*, 22nd February 1901, p. 215.)

It has been shown, both by analysis of Chinese glazes and by actual European practice, that not more than one-half per cent. of copper oxide is needed to give the richest and most solid red." (*Ibid.*) "The really important part is the production of a glaze which will melt and come perfectly bright and glossy in a reducing atmosphere." (*Ibid.*)

The methods pursued by Chinese ceramists in the production of copper-ruby glazes have been described by Dr. Stephen W. Bushell, M.D., C.M.G., on p. 139 of this volume, to which the reader is referred.

Ruby-Lustre. — A practical English "ruby lustre" artist gives the following directions and general information as to his method of procedure. Brown oxide of copper is the base: outlines and darkest parts are done with a composition of about equal parts of calcined boracic acid and copper sub-oxide, the calcined boracic acid being prepared by filling a small saggar with boric acid and then sprinkling over it a little granular metallic lead. (*Hence, to be more exact, and presuming our informant had mistaken crushed galena for metallic lead, the product he calls calcined boracic acid would be a more or less indefinite compound of boric acid and lead borate.*)

The above-named composition for outlines is mixed with sulphur and calcined earthenware clay, and ground finely for use in painting lighter parts. The lighter the required tint, the larger the proportion of clay used in the mixture. As a medium to facilitate its application, he advises Canada balsam. When the painting is on, the work is to be allowed to dry and to set hard. Then, before putting the work into the kiln, apply a medium wash over it of flint and calcined earthenware clay mixed in water.

Firing is done at a red heat. When this heat is attained, open a door that is provided near the bottom of the kiln and push in some very dry gorse or

brushwood; this causes a flash which develops the lustre. As soon as the kiln contents have thus been flashed, pull out the fires. The heat attained is about half enamel-kiln heat, and the time four hours. When cooled, and when the articles are drawn from the kiln, rub off the flinty wash, and also rub off the under scum.

For Pearl Lustre, the same artist directs a similar process, but using chloride of silver instead of copper oxide.

English Lustres.—The following recipes describe a series of lustres of a sort that have been in use for ornamenting china and earthenware in Staffordshire and other British pottery manufacturing districts a very long time. They are, in reality, rather opaque metallic films than lustres. Their invention and use antedate the De Morgan lustre rediscovery; and in Shaw's *Chemistry of Pottery* their introduction is attributed to John Hancock, John Gardner, and William Hinns.

Bismuthic Iridescence.—A sort of mother-of-pearl lustre or iridescence has long been almost a speciality of the Belleck Pottery Co., Fermanagh, Ireland.

The following purports to be a practical recipe for producing such an iridescent effect, and it is inserted without guarantee:—

REQUIREMENTS.—A sand-bath, milk-pan, and a coke fire without blaze.

MATERIALS.—5 ozs. white resin, 1 oz. bismuth nitrate, 12 ozs. oil of spike.

PROCESS.—Place the sand-bath on the coke fire, having the milk-pan well sunk into the sand, and put in the 5 oz. resin. When the resin is thoroughly melted, add the 1 oz. nitrate of bismuth, and stir well with an earthenware spoon, or the handle of a soup-ladle; keep same for one hour at a good heat, stirring without ceasing. After adding the nitrate, the resin will froth up and swell, and brown nitrous gas will be evolved. When the whole of the resin has dissolved the bismuth, all action will cease and the mass become nearly black. Remove from fire and let it partially cool, scraping down any that may be upon the side of the pan. Add little by little the oil of spike, stirring all well until the 12 ozs. is added, then pour the composition into a wide-mouthed bottle. Apply the lustre with a pencil smoothly and evenly, and fire about the heat of a hardening-on kiln. Enamel-kiln heat will burn it all off.

Iron Lustre.—Dissolve iron nails in nitric acid, and while hot pour the solution very gradually into best brown tar, taking care to stir well all the time. Great care is required in the preparation, and success only acquired by practice. The tint of the lustre is acquired by the quantity of solution added, say ½ oz. of solution to a pint of tar. Continue stirring the tar as you add the solution, and until all chemical action ceases; then, after allowing the mixture to rest about forty-eight hours, pour off the surface, avoiding all sediment.

Steel Lustre.—Dissolve platinum in aqua-regia, then drop the solution gradually into three times its weight of spirits of tar. If too thin, thicken by evaporation. It must be used only with spirits of tar, when applying to the wares.

Silver Lustre.—Precipitate platinum from its solution in aqua-regia by means of ammonia, wash the precipitate, and mix it with water of sufficient consistency to lie upon the steel lustre, above described, after application to the ware; and then burn the ware a second time at blood-red heat. It must only be laid on thinly on account of its cost.

Gold Lustre.—Take a glass bottle, about 7 inches high and $1\frac{1}{4}$ inch wide, with wide neck; warm it slightly, then put in it $\frac{1}{2}$ oz. of yellow grain gold and 1 oz. by measure of nitric acid, agitate gently for fifteen minutes; then add 2 ozs. by measure of muriatic acid, agitate gently for several minutes. Do not cork the bottle, but merely cover the mouth with a fragment of glass or pitcher. Then place the bottle in a tall mug on the hot-plate of a stove, and allow it slowly to become very hot. When solution is complete, remove the mug and bottle from the hot-plate, and let the whole cool down. When cool, add 10 grains of tin, and warm again as before for half an hour. Then allow the solution to cool and rest for fifteen hours.

Afterwards take a large wide-mouthed jug, and weigh or counterpoise it on the scales; then weigh into the jug 6 ozs. of balsam of sulphur, followed by $1\frac{1}{2}$ pints of turpentine; stir these together for an hour in a warm room, gently warming if necessary.

Cool this compound down perfectly cool. When cool, drop the acid solution of gold and tin little by little into the turpentine and balsam mixture, stirring continuously with a wooden ladle, and continue stirring for four hours incessantly. At the end of the first hour or thereabout, the mixture will probably become very hot; this is when combination is taking place. The lustre is then ready for use. By increasing or reducing the relative proportions, the strength may be modified according to desire.

In Corfield's book of recipes a somewhat similar series is given, and a variety of tints attained by mixing. For instance, blue-green lustre is a mixture of yellow lustre and gold lustre; green lustre, similar, but using less gold lustre; and so on.

Lustre Kilns.—The old style of enamel kilns are best for lustre, because a much quicker fire is given; otherwise you don't get the proper brilliance. These fire about eight hours, whereas ordinary majolica-tile glaze kilns fire from fourteen to sixteen hours.

CHAPTER XIV.

CONSTRUCTIONAL FAIENCE AND ENAMELLED TERRACOTTA.

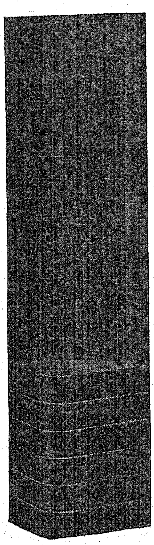


FIG. 285.—Faience hob side.

AN almost inevitable consequence of the use of richly glazed tiles for interior decoration would be the need of ceramic mouldings to form a termination or framework.

The incongruity of a tiled dado with a wooden surbase, or, indeed, of any considerable surface of wall-tiling bounded by woodwork, stonework, or cement stucco, would probably soon become apparent, and something more appropriate would be sought. Faience mouldings thus being introduced, their manufacture and use would naturally lead to further applications of the material; and by gradual development and progressive improvement in methods of manufacture, modern chromo-faience for constructional and semi-constructional purposes, as it may now be seen in many large cities, has been evolved.

In a former chapter the early arduous and enterprising labours of pioneers, such as Herbert Minton and George Maw, have been briefly reviewed. It is therefore now only necessary, in noting the chief incidents of the evolution of this industry, to mention others who, although arriving on the field somewhat later, and by different routes, have nevertheless attained eminence in the manufacture, particularly of constructional faience.

Messrs. Doulton & Co., of Lambeth, London, claim to have manufactured both salt-glazed ware and glazed faience for architectural purposes since A.D. 1873.

Mr. W. P. Rix informs the writer that the first glazed majolica fireplaces were prepared for the Philadelphia Exhibition of 1876. So early as 1872, he

says, a very fine modelled terracotta mantelpiece was exhibited, but that was unglazed.

In 1880 Mr. John C. L. Sparkes, who had previously read a paper before the Society of Arts (on 29th April 1874) about Lambeth pottery, remarked that "Much had been done since that time, and notably in the new buildings on the Albert Embankment, which are entirely built and decorated with bricks, terracotta, and stoneware. Not a piece of stone is visible anywhere in the whole of that remarkable elevation. Many of our architects have seen the suitability of this fine material for decoration, but by the generality of them it is still neglected. . . . After complimenting the artists for loyalty and Mr. H. Doulton for his wisdom in giving them rein, Mr. Sparkes continues:—"The whole result of the few years' work is the more gratifying, inasmuch as we started in a perfectly new venture, without a single grain of experience to help us in the composition of stoneware colours, and with almost everything, except the general knowledge of the ware, to learn. You see how well the lessons, bought by experience, have been learnt, and can judge of the success the Lambeth Potteries have made. It is a truly national production, inasmuch as not a single stoneware-producing district abroad has attempted to develop anything out of the art taught them by their ancestors: it is local, and is the direct outcome of the proper co-operation that ought to exist between schools of art and local manufactures. . . . As I know that the past six years has developed a new art in stoneware, and almost a new art—at any-rate in Lambeth—in faience-painting, so I venture to predict that another six years in the future will see as much advance on what we look on to-night as it is in advance of what we saw in 1874." (*Jour. Soc. Arts*, 12th March 1880, p. 355.)

About 1880, John Harrison, of Linthorpe, near Middlesborough, was manufacturing attractive art-pottery, mostly of red-colour body, and in æsthetic shapes, "thrown" and often completely finished, so far as making, on the wheel. These wares were glazed with exceptionally rich-looking and probably easily-fusing glazes, usually transparent, and frequently stained with colours. In connection with some of the glazes used at Linthorpe, Mr. C. H. Read, F.S.A., tells us he understood that a Japanese potter was imported to conduct the experiments. (See *Jour. Soc. Arts*, 22nd February 1901, p. 221.)

At a similar period, or possibly rather later, the firm of Wilcocks & Co., of Burmantofts, near Leeds, appear to have begun to apply easily fusible coloured glazes very like Linthorpe glazes to wares composed chiefly of the slender fireclay found on the site of their works. The nature of the clay lending itself more readily, perhaps, to the manufacture of large pieces than did the fine earthenware bodies of Staffordshire, its application to constructional faience would thus be facilitated.

In 1887 an important change occurred at these Burmantofts works, and

Keramic Gallery, Victoria and Albert Museum.
The ten columns supporting the roof of this gallery are covered with embossed and glazed tiles from the manufactory of Minton & Co.
(Illustrated by permission of the Board of Education.)

the management was then taken over by Messrs. Holroyd & Armitage. Thenceforward more energetic measures were taken to place the faience products and glazed bricks on the market in a more extensive way, and the business has since made continued and considerable progress.

Since 1873, as we have already stated, Mr. William De Morgan has been devoting special attention to the rediscovery and reintroduction of lustre-wares and other products after the manner of mediæval Persian and Hispano-Moresque work. He tells us he had practically perfected the lustre process so early as 1873–1874, developing it first in Chelsea, where he accidentally set fire to his house and burnt the roof off. Mr. Lewis F. Day speaks of W. De Morgan thus—" At one time he imported tiles from Stourbridge, and would only paint them at his pottery ; but as all the tiles in the Potteries are made of *compressed* dust, they will not stand exposure to the varying temperature without breaking or the surface flaking off. . . . Now he makes his own tiles from clay sent from Stourbridge, mixed with ground firebrick and old saggars. These tiles stand the weather perfectly, as a specimen showed to me testified, which had been in a London window-box for eleven years. The painting, too, instead of being done on the tile itself, is done on thin paper, and this is stuck down on the surface of slip which De Morgan always uses to cover the dark body. The glaze is then put over the paper, and in the firing this easily disappears. . . . . But whereas he (De Morgan) adopted the old method, so far as it was discovered, his imitators appear to have clung to the lead glaze it was their habit to use." (*Art Journal*, 1895, pp. 311 and 345.)

One by one other manufacturers entered the trade, including eminent firms such as Craven, Dunnill, & Co., of Jackfield ; Campbell Tile Co., of Stoke-on-Trent ; Woolliscroft & Son, of Hanley ; J. C. Edwards, of Ruabon ; Carter & Co., of Poole ; The Della Robbia Pottery Co., of Birkenhead ; George Swift, of Liverpool ; Pilkington Tile and Pottery Co., of Clifton Junction, near Manchester ; and others.

Thus during the latter part of the nineteenth century a new branch of ceramic industry grew up, devoted especially to the manufacture of mouldings, plinths, corbels, and other architectural details of a more or less constructional character in chromo-faience, for the *interior* decoration of public buildings in conjunction with glazed decorative tiles. The delights of these pleasing displays of colour and effective designs, together with freedom from that *bête noir* of most other building materials—the necessity for frequent redecoration—contributed to success ; and it became evident that, if only chromo-faience could be manufactured so as to fulfil all the requirements essential to *exterior* construction, a still wider field would be opened up to ceramic art.

Marble, granite, freestone, bricks, terracotta, cement, all serve a purpose, as far as inherent qualities permit, and will continue to do so ; but architects

are fully conscious of shortcomings in these ordinary building materials. Marble and stone weather away, bricks and terracotta often become begrimed, cement work and fresco suffer grievously under the influence of damp and are troublesome to redecorate; hence, for certain situations, something of a less absorbent, less easily begrimed, more lively coloured and light-conserving nature is desirable.

Many architects had seen or read of the glittering minarets and domes and enchanting chromatic exteriors of Eastern mosques and palaces in Persia, India, Bokhara, etc., which travellers confessed they could but very inadequately describe; and they yearned for a little of this gorgeousness at home.

When addressing the Society of Arts early in 1902, Halsey Ricardo pleaded eloquently for an abandonment of the "tame respectability of stone," and for "the external use of colour decoration of a permanent kind, got either by enamelled tiles, glazed faience, or mosaic. . . . . The result of this stony disdain, this proud scholarship of our streets," he continues, "is that we can't live in them. Every evening thousands upon thousands escape by every railway from these masterpieces of correct architecture . . . . to the shelter of the country, where the earth is green about them and the heaven blue above them. Cannot we," he asks, "make our streets a little more kindly and comforting to those poor prisoners who cannot escape? We have tried mass, and form, and light, and shade; might we not now have an attempt at colour?" (*Jour. Soc. Arts*, 24th January 1902.)

In attempting to comply with such demands and to satisfy these longings, ceramists inevitably, at first, fell into some errors. At the outset the changes necessary to meet the new set of conditions arising in exterior work could not be accurately gauged and provided for; the limitations of the material were perhaps not fully realized in the absence of experience.

If manufacturers could have had resort to the knowledge acquired by Girolamo della Robbia, who, during forty years of arduous toil and application, little by little solved the problems involved in the designing, manufacturing, and construction of his famous and beautiful Château de Madrid in Paris, with its statues, relievos, columns, chimney-pieces, galleries, terraces, and roofs of faience, they and their artist and artisan ceramists of the nineteenth century would have greatly benefited.

But this could not be; old difficulties arose for the Briton, just as they had arisen for the Babylonian, Egyptian, Persian, Syrian, mediæval Hindoo, and Renaissance European. By careful research, some of these obstacles were overcome; while other things, owing to their seeming impracticability, have been relinquished.

All this has been so well expressed by a correspondent of the *British Clayworker* of August and October 1898, that, with due acknowledgment and apology, the writer ventures to make some excerpts therefrom.

"Turning our attention . . . . to the practical application of majolica to architectural purposes, we have first to note that these divide themselves into the four very distinct sections, viz., interior decoration, exterior decoration, constructional work, applied work. The material hitherto largely used for architectural majolica has been of too porous a nature to allow of its use in exposed positions, and the difficulty which most manufacturers have experienced in their results has been largely due to this cause. It is, undoubtedly, necessary to retain a fracture to the body which will allow of its being worked by the fitter after coming out of the kiln; but this property should not be obtained by soft-burning of the biscuit, but by the use of a finer refractory material fired at a high temperature. With a proper adjustment of the amount of plastic and vitreous clay to bind the coarser particles, a body may be obtained which will not only stand a great crushing strain, but will also resist frost, and be found far less liable to shell. In constructional faience for exterior use it is most important to give attention to this point. . . . Again, in the matter of glazing . . . . the constitution of transparent majolica glazes causes it to become as fluid as water during firing. It therefore speedily flows to the lowest point of the surface. Under such conditions it is obvious that entire uniformity of tint cannot be maintained. . . . Some architects have wisely accepted the variations of shade as adding interest and richness to the general effect. Others . . . . have declined to pass anything short of uniformity in colour. For such demands transparent majolica glazes are wholly unsuitable.

"Another and perhaps equally important question to be decided is that of the surface texture of the ware. There is no doubt that for exterior surfaces the flecking of light on the highly reflective glaze is very detrimental to the general architectural effect, as it destroys the repose and breadth of appearance, besides interfering in many cases with the full value of the light and shade in the moulded and modelled portions. Several very successful attempts have been made to overcome this disadvantage by the use of glazes with a 'matt' or non-reflective texture, a notable instance of which may be seen in the exterior of the new Birkbeck Bank building in Chancery Lane, London, by Messrs. Doulton & Co.

"Though the advantage of the matt surface is obvious in exterior application, the question is open to some diversity of opinion as regards interiors. . . . . No doubt . . . . the reflection of light from a wall surface, especially from modelled friezes or pilaster panels, adds greatly to the brightness of an interior, and unless there is a flood of top light the work does not greatly suffer. In ecclesiastical work, or in the case of painted subjects, of course this reflection of light is to be avoided as interfering with the general effect, and the adoption of a fresco-treatment for the latter in matt enamels is far better than underglaze painting.

"A question here arises which has provoked some difference of opinion. Is crazing to be considered a defect in majolica? From an artistic point of view there are undoubtedly many arguments which may be urged in its favour. Many cases may be cited in which crazing distinctly helps the appearance of wares rather than mars it. . . . . From a technical point of view, it has lately become the fashion to denounce crazing as an aggravated form of bad potting. It is argued that crazing is due to an inequality of contraction and expansion between body and the glaze, which ought, in these scientific days, to be altogether overcome. All these arguments may be equally sound if considered on their merits; but, after all, the practical questions must outweigh the rest. Is it possible, with due regard to economy in production, to obviate crazing? And is it any advantage to do so? To the first question a qualified affirmative may be given. If the choice of material is unlimited, the prevention of crazing can be easily attained by proper adjustment of proportions in both body and glaze. But the practical potter knows to his cost that there are very few instances in which such conditions exist. . . . . Sometimes a harder fire may produce a satisfactory result. But this again adds fresh expense. Too often the contractor and the architect are ready to give the work to the cheapest producer, and it is not surprising that crazing is allowed to take its chance, unless its absence is insisted upon.

"It therefore becomes important to inquire if there is a real advantage obtained by insisting on this freedom from craze. For interior work there does not really appear to be much reason to do so, except in the case of opaque enamels or very light-toned glazes, where there is much wear and tear.

"Sometimes crazed ware is so widely open at the glazed cracks that dust and dirt easily enter and emphasize the defect by unsightly black lines, which, once filled, can never be removed again, and on light ware become an eyesore. But in rich schemes of colour this danger does not arise. When, however, we come to ware intended for exterior application, we have to give an emphatic vote in favour of no crazing." (*British Clayworker*, August and October 1898.)

The complexity of the problem of constructional faience for exterior work is thus confessed by one who clearly is in the truest sense a master of the art. He seems to demonstrate that the glazing of terracotta with easily fusible glazes of the usual composition, containing lead, demands conditions inimical to the durability of wares which are expected to bear exposure to the humid and often acidulous atmosphere of British cities. The façades of Birkbeck Bank, however, which he mentioned, should not be classed as faience. Messrs. Doulton & Co. state that both the ware of the Birkbeck Bank in Holborn and that of the offices of the *Sheffield Daily Telegraph* in Fleet Street are what they call "Carrara enamelled

stoneware," which, unlike majolica faience, is completed in one hard-stoneware fire. Indeed, Messrs. Doulton & Co., whose long and varied experience should give them a pre-eminent right to speak with authority, say:—"Majolica . . . . does not admit of being fired to such a degree of hardness as is desirable for exterior decoration in this climate." (*Description of their Works, etc.*, pp. 43–44.)

In like manner, the experienced firm of J. C. Edwards (Ruabon) write:—"I do not recommend or advise the use of soft glazes for external work. . . . . I make and supply faience in all the usual majolica glazes and enamels, also in special semi-opaque (or eggshell glazes), the latter especially being used for exterior and architectural uses."

But if ceramists have met with some initial disappointments in the manufacture of chromo-faience for exterior construction or application, they, at least, are not alone. Has not Halsey Ricardo admitted that "Not only the science of architecture, but the beauty, which is the cream and bloom of science, grew up from the careful observation of building disasters and the invention of expedients that might obviate their recurrence." (*Jour. Soc. Arts*, 24th January 1902, p. 164.)

And did not Sir W. B. Richmond, A.R.A., say, with reference to the mosaics of St. Paul's Cathedral:—"In the work which has been recently uncovered, I believe that most of the faults which I have confessed to exist in my previous efforts have been overcome. At the same time, we are all learning; every day of experience brings new light upon our beautiful art." (*Jour. Soc. Arts*, 26th June 1895, p. 724.)

Chromo-faience and enamelled terracotta admittedly have limitations, just as other building materials have. Each fills its own sphere with advantage, and must await the touch of genius for further extension of application. As a rule, it is better to use well and improve, each in its proper place, than to attempt to unreasonably extend.

For both interior and exterior decoration in dry climates, and for interior work in humid climates, chromo-faience—usually called *Majolica*—may long fulfil a useful and beautifying purpose, at once hygienic and museaic.

But for exterior building construction and adornment in humid and variable climates, particularly in towns where an acidulous atmosphere prevails and frosts are of frequent recurrence, further effort is demanded of ceramists.

This has been seriously attempted both in England and on the European Continent—Emile Muller & Co., of Ivry-port near Paris, and Villeroy & Boch, of Merzig and Mettlach, Germany, having been very successful.

The success of the first-named firm was exemplified in their exhibits at the Paris Exposition of 1900, where, along with some fine friezes and ornamental glazed bricks, was to be seen a beautiful specimen of the potter's

art in the shape of a fountain, consisting of a finely modelled figure-group by A. Mulot.

In England, Messrs. Doulton & Co., of Lambeth, have paid great attention to this matter, their salt-glazed decorative stonewares and their "Carrara" enamelled stonewares all testifying to a correct apprehension of the requirements of the case, and conspicuous ability and success in efforts to meet them.

Of their polychrome stoneware, Messrs. Doulton & Co. say:—"The development of majolica painting, known as stoneware polychrome, invented and first used in 1898, offers facilities for permanent *exterior* decoration, a desideratum long felt by architects and designers. In this method the decorations are fired at the same stoneware fire as the slabs or blocks on which they have been painted, and are thus absolutely permanent, and able to withstand the most trying atmospheric conditions." (*Description of their Works, etc.*, p. 27.)

In the same brochure, on p. 44, they remark:—"Under the name of 'Stoneware Polychrome,' Messrs. Doulton & Co. have sought to carry out on a stoneware basis the method of decoration known as majolica painting. . . . . Experiments have led to the preparation of a hard stoneware body and an enamel covering, which can be fired at the same stoneware heat as the body itself and in the same kilns. Paintings fused at such an intense heat as this are not likely to be attacked by the deleterious acids found in city atmospheres; and the decorative scheme once decided upon will remain permanently enshrined."

The writer understands that as yet stoneware polychrome is not used largely, but salt-glazed stoneware (known as "Doulton ware") is finding almost universal acceptance with architects.

Of this colour-decorated, salt-glazed stoneware, Messrs. Doulton & Co. say:—"One of the striking peculiarities of the salt-glazed Doulton ware is that its decoration is entirely completed in the plastic state. This is a method little used by other potters, and is, in fact, both a condition and an advantage of the salt-glaze method. We see at once, on watching the artists at work, how easy it is to manipulate, carve, twist, and model the soft form. . . . .

"The most important method (of ornamenting it) is that of *incising* an ornamental pattern, the artist cutting into the clay with a sharp tool, which throws up a fine burr on either side to retain the colour afterwards applied. A method recently introduced utilises a freely drawn *brush-line* in place of the incised line. This has given greater freedom of execution, although adding somewhat to the risks of colouring and firing. . . . .

"As soon as the plastic decoration is completed the pieces are put aside to dry before colouring. Unless this drying is perfect, disaster is sure to result in the kiln. When Messrs. Doulton first introduced coloured salt-glazed

ware . . . . only two or three simple blues and browns were employed, such as were used before on the *grès de Flandres*; but the palette has gradually been extended, until they have now a much greater range of pigments adapted to resist the intense heat of the kiln. These Doulton ware colours at their best are wonderfully lustrous and varied. . . . . They are, in fact, glasses; intensely hard, absolutely permanent, capable of resisting atmospheric or chemical corrosion, and calculated to retain their beauty for long ages. Added to this intrinsic excellence, there is an absence of mechanical uniformity in the colour, which is the natural outcome of the open fire in which the pieces are baked.

"Although Messrs. Doulton & Co.'s experience of stoneware now extends over many years, the anxieties attendant upon the production of an art-stoneware have by no means lessened. The risks are no less numerous than in the early days; the firing still has to be carried through in large open kilns, liable more or less to varying conditions, so that, although within certain limits effects and combinations of colour can be prepared for, the main factor in a successful result is still a matter of fortunate chance.

"As regards the types of design that may be seen, Messrs. Doulton & Co. may claim with pride that they have carried the possibilities of art-stoneware to a point beyond what had hitherto been attained. They have discovered and used successfully many new colours; they have added to their already numerous methods of dealing with the plastic material; and, on the other hand, they have to some extent relied upon simplicity of form and economy of means to produce a new order of effects." (*Description of their Works and Manufactures*, 1900.)

An example of the architectural use of Doulton's salt-glazed stoneware is the *Pearson's Magazine* Buildings, Henrietta Street, London, W.C.

Taking a peep into the near future, we learn from *The Pottery Gazette* that the Sèvres Porcelain Co. are shortly to erect a porcelain tower on the heights of St. Cloud, near Paris, which promises to be a striking feature. "It is to consist of thirty thousand separate pieces, carefully tested, and decorated with specially prepared designs in all the colours of the spectrum. It is expected that the structure will take about five years to erect, and that, when completed, it will equal, if not surpass, the finest of its numerous Chinese prototypes." (*Pottery Gazette*, 1st August 1903, p. 803.)

Bodies for Constructional Faience.—The composition of the bodies unavoidably differs in different works. In one instance the industry may have been developed upon premises erected in proximity to a large city, with the primary object of conveniently supplying local demands, and may have no special ties in respect of clays. In other instances, faience plants may have been erected upon certain clay-beds with the object of making profitable use of the particular materials existing there. Bodies used at such works

must, therefore, be compounded in such a manner as to include the largest practicable proportion of clay found on the site.

But clay-beds themselves differ; consequently the mixing of the bodies must be varied accordingly, and in all instances glazes must be compounded to suit.

For these reasons special expedients are resorted to at the several works, with the object of bringing this more or less motley group into line, so as to meet the fashions of the hour. Slowly, manufacturers are taught, by individual experience, what is and what is not commercially practicable in their respective circumstances; and, after worrying through initiatory difficulties, each in turn adapts his works and methods to the class of products that suits him best.

Speaking generally, it is desirable that clays for constructional faience bodies should either of themselves be able to bear the necessary burning, without twisting, splitting off, cracking, bursting, and a few other only too well-known vagaries of clays; or be capable of admixture to enable them to do so. The resulting ware should be susceptible to glazing, and as nearly imperishable as practicable in use.

Body compositions for small pieces may partake either of the character of good white earthenware, such as that used for glazed tiles, or of coarser ceramic compounds. But for all large pieces the bodies should assimilate more and more to those of buff terracotta of the fireclay class. These fireclay bodies, however, being of comparatively dark colour, have a very decided effect on the colour of the glazes employed, reducing their tone materially. Hence, sometimes an engobe or surface slip may have to be applied to secure a better glazing surface. Occasionally native clays are met with, even of the fireclay class, that possess almost insuperable tendencies toward crazing the glazes. Nor does it always follow that a coarsely siliceous clay will invariably be best, for fine-grained clays often prove exceptionally good.

Others are disposed to cast off the glazes, and may sorely task the resources of the ceramist. Even the several separate seams of clay of the same pit exhibit very great differences in their behaviour in regard to glazing. To ascertain approximately what this really is, it is necessary to test each clay separately. The experiments may be conducted on the following lines:—Taking each sample separately, pulverize so as to pass a 32^h mesh sieve. Mix with sufficient water to bring the clay into a plastic condition, then weigh, and from the weight calculate the proportion of water that has been added to bring the clay into a suitable condition. This may give an indication of the degree of shrinkage to be anticipated.

Beat out the plastic mass and cut into small slabs, mark two points on each slab at a distance of one hundred 64ths of an inch ($1\frac{9}{16}$ inch), or by

metric distances of any convenient length, and place aside to dry; or mould the test-pieces in steel or plaster moulds of equal length. When dry, measure between the marked points and record the measure and shrinkage, at the same time noting which of the slabs have retained good shape during drying.

Burn the test-pieces in different parts of a suitable kiln, preferably where the heat attained can be ascertained by a pyrometer; and when the pieces are withdrawn and cooled, measure again between the marked points, register the extent of contraction, and notice any susceptibility to change in form or colour, and the degree of porosity or vitrifaction.

Afterwards dip half of each test-piece in glaze of known quality; burn again and note results.

Another portion of each sample of clay should be soaked in water for a few days, then blunged into a creamy condition (slip) and sieved through a 60^h mesh sieve; the slip brought to a plastic condition, by drying or pressing, and test-pieces made, marked, and tested as with the foregoing series.

From the results of such practical tests the means requisite for compounding a suitable body will be roughly indicated, and more elaborate compounds, if necessary, may then be prepared of the most promising quality or mixture of several qualities.

The following recipes may serve as a guide or basis for actual tests, but will have to be modified in individual instances for the reasons just given.

RECIPES FOR BODIES FOR CONSTRUCTIONAL FAIENCE.

No. 1.—Faience Body (for interior work).

300 lbs. buff-burning slender fireclay.
48 „ china-clay (kaolin).
44 „ ground calcined flint.
10 „ „ china-stone.

Two methods of preparation :—

(*a*) Soak in water, blunge into slip, sieve the slip through a sieve of 60^h or 80^h mesh. Get to a plastic state either by boiling on a quarried kiln or by means of filter-presses. Age the clay for about fourteen days.

(*b*) Grind the compound under edge-runners so as to pass 32^h mesh sieve; mix with water in a wet pan, and afterwards pass the clay through a pug-mill, and age it fourteen days.

No. 2.—Faience Body.

Prepare a common white body consisting of—

44 inches	ball-clay slip	at 24 ozs. to pint.
13 „	ground pitchers slip	„ 31 „
11 „	calcined flint slip	„ 32 „

Mix and blend the above for two hours, then sieve through a 60[ll] mesh sieve, and dry either upon a drying kiln or by filter-press.

Then grind together the following mixture in an edge-runner mill, with a suitable proportion of water:—

4 cwts. dry white body, as above.
1 „ „ peacock marl (fireclay).
1 „ „ sand.

After removing from the pan, pug and age the clay.

No. 3.—Faience Body.

160 lbs. dry Devonshire ball-clay. 120 „ „ ground calcined flint. 125 „ „ „ biscuit pitchers. 100 „ „ strong fireclay. 100 „ „ calcined sand.	Grind under edge-runners to pass 32[ll] sieve; wet-grind and pug.

No. 4.—Faience Body (for slabs for slip-painting).

20 lbs. ball-clay.
20 „ china-clay.
10 „ fire-clay, sieved through 32[ll] mesh sieve.
8 „ ground calcined flint.
5 „ „ Cornish china-stone.
5 „ „ pot (or calcined fireclay).

Do not pass it through a finer sieve than a 32[ll] mesh; stiffen, and keep it in a plaster-lined box.

N.B.—This recipe is reprinted from *The Manufacture of Glazed Bricks and Glazed Sanitary Ware*, by kind permission of H. Greville Montgomery, Esq., of *The British Clayworker*.

No. 5.—Faience Body.

500 lbs. buff-burning slender fireclay.
150 „ calcined fine silica sand.

Soak in water, blunge into slip, pass through 60[ll] mesh sieve, stiffen on a quarried kiln, then pug or wedge.

No. 6.—Faience Body.

900 lbs. buff-burning slender fireclay.
100 „ ground burnt biscuit body.

Prepare by either method suggested in No. 1 recipe.

No. 7.—Faience Body.

750 lbs.	slender fireclay,	ground to pass	12^h	mesh.
230 „	ground grog,	„ „	20^h	„
20 „	sawdust,	„	20^h	„

Mix and grind in solid-bottom edge-runner pan about fifteen minutes. Wet and pug, or wedge.

No. 8.—Faience Body.

850 lbs. strong fireclay, to pass 12^h mesh. 150 „ ground grog, „ 20^h „	Prepare as No. 5.

RECIPES FOR BODIES OF FAIENCE-GLAZED BRICKS.

No. 1.

8 cwts. ground fireclay, 12^h mesh. 2 cwts. ground grog, 12^h mesh.	Mix and grind stiff with water, twelve minutes in solid-bottom pan of edge-runner mill. Age fourteen days.

If needed finer, pass through 16^h mesh to inch.

No. 2.

6 cwts. ground fireclay, 12^h mesh. 2 „ „ biscuit pitchers, „ 1 „ „ sandstone, „	Treat as No. 1.

No. 3.

9 cwts. ground fireclay, 12^h mesh. 1 „ „ grog, „ 14 lbs. sawdust, „	Treat as No. 1.

No. 4.

6 cwts. strong fireclay, 12^h mesh. 3 „ slender „ „ 1 „ ground grog, „	Treat as No. 1.

RECIPES FOR DIPS OR ENGOBES.

These are for surface application to the glazing faces of constructional faience, or of faience bricks when the body itself does not yield a suitable glazing surface. The particular dip or engobe selected should fire up or mature properly at the heat at which the piece of ware or brick becomes soundly and satisfactorily burned in the biscuit state. This heat will, of course, differ with different fireclay bodies. The dips must also be compounded, and, if necessary, modified so as to suit the glazes it is intended to apply, both as to colour and chemical nature.

To prevent "crawling" of the dips or engobes, the addition of a proportion of 5 per cent. solution of carbonate of soda is sometimes recommended, and this may be resorted to when necessary.

No. 1.—Faience Engobe.

Slender fireclay alone, weathered and hand-picked.

Soak in water two days, then blunge up into a slip of cream-like consistence, and sieve through 60^h brass-wire sieve; get to 27 ozs. weight to pint and mellow ten days.

No. 2.—Faience Engobe.

10 pints of No. 1 fireclay slip at 27 ozs. to pint.
10 „ No. 3 white-body slip „ 28 „

Mix together intimately, sieve twice through 80^h mesh sieve, mellow four days.

No. 3.—Faience Engobe or "White Body."

4 lbs. ball-clay. 4 „ china-clay. $2\frac{1}{4}$ „ ground flint. $2\frac{1}{4}$ „ „ china-stone.	Soak in water, blunge into slip, sieve through 80^h mesh sieve, get to 28 ozs. to pint, mellow ten days.

No. 4.—Faience Engobe or "White Body."

10 lbs. ball-clay. 7 „ china-clay. 7 „ ground flint. $2\frac{1}{4}$ „ „ china-stone.	Soak in water, blunge into slip, sieve through 80^h mesh sieve, get to 27 ozs. to pint, mellow ten days.

No. 5.—Faience Engobe or "White Body."

10 lbs. china-clay. 2 „ ball-clay. 2 „ ground china-stone. 1 „ „ calcined flint. 1 „ whitening.	Treat as No. 4, but get to 26 ozs. to pint.

NO. 6.—FAIENCE ENGOBE OR "WHITE BODY."

10 pints dip No. 4 at 27 ozs. to pint. 10 pints dip No. 5 at 26 ozs. to pint.	Mix together, sieve through 80[h] sieve, mellow four days.

NO. 7.—FAIENCE ENGOBE OR "WHITE BODY."

$7\frac{1}{2}$	lbs. china-clay.	Treat as No. 4, but get to $26\frac{1}{2}$ ozs. to pint.
$4\frac{1}{2}$	" ball-clay.	
4	" ground china-stone.	
$1\frac{3}{4}$	" " calcined flint.	
$1\frac{1}{4}$	" whitening.	
1	" plaster of Paris.	

Preliminaries of Manufacture. — In actual practice an essential preliminary is the preparation of appropriate and workable designs. To accomplish this satisfactorily, a knowledge of the several styles of architecture is necessary in addition to a general art-training, so that incongruities may be avoided.

Effective schemes of embellishment having been planned, whether by architect or designer, a drawing showing the elevation should be made to a scale of 4 feet to an inch. If required, the artist-designer may then with greater exactness work out the more elaborate details. Afterwards the draughtsman proceeds to make full-size drawings of the pieces, and from these drawings models are subsequently made by which the clayworker or "faience-maker" is enabled to reproduce in clay what was intended and represented by the designer or architect.

In connection with outside work, care should always be taken to provide proper drip to all projecting mouldings, so that when the pieces are placed in position rain-water may not lodge upon them.

Making the Moulds.—Excepting "majolica" glazed bricks, which may be either hand-moulded or machine-made, and possibly some small plain mouldings, which may, when many of the same section are required, be made by a machine known as a "stupid," constructional faience and the larger pieces of applied faience are usually made plastic in plaster moulds. (See *Brick and Pottery Trade Journal*, May 1903.)

To prepare these plaster moulds, it is necessary first to make a model of the desired piece. This may be done either by carving in wood and varnishing the model, by carving in stone as a stonemason does, and in other ways; but the most customary method of preparing models for the majority of faience

mouldings, etc., is to make them in plaster, or part plaster and part clay, in the following manner:—

First of all, a full-size sectional drawing should be made of the piece or part required; this must be drawn to a shrinkage scale suited to the clay of which the ware is to be made. For, as the pieces will be made of clay in a plastic condition, contraction during drying and burning will probably amount to from $8\frac{1}{2}$ to 12 per cent., according to the constituents of the body and the degree of heat attained in burning.

Presuming the shrinkage anticipated is one-twelfth, proportional enlargements may be ascertained as follows:—Upon any convenient board or paper describe two concentric circles having radii respectively 11 inches and 12 inches, or 12 inches and $13\frac{1}{11}$ inches; and draw a straight line from the centre to outer circle.

To enlarge, measure from the point of intersection of this straight line on the smaller circle the length required to be enlarged, and mark the smaller circle at the desired distance: through this mark draw a straight line from the centre to the outer circle; the distance between the points of contact of these two straight lines with the outer circle will be the desired enlarged measurement.

In like manner, if the shrinkage anticipated is one-eighth, describe concentric circles having radii respectively 7 inches and 8 inches, or 14 inches and 16 inches, and proceed as before.

When designing and when making models for faience, it is of utmost importance to provide that the clayware will come away from the working moulds easily, and without injury to any arrises or enrichments. The designer acquainted with the technical difficulties to be encountered in producing wares of this class gives this essential condition his first consideration when preparing designs for constructional pieces, for it is important that undue handling of the clayware in a plastic state, owing to moulds being unnecessarily intricate, should be avoided.

The required full-size drawing having been made, with due regard to the points mentioned, it is handed over to the carpenter or to the modelmaker, who traces the outline through it on to a piece of thin sheet-zinc. The profile or section thus traced is then carefully cut out of the sheet-zinc by means of a keyhole saw, and this zinc profile or templet nailed firmly on a piece of wood shaped approximately to the zinc profile, to support and strengthen it. This piece of wood is called a "mount."

As an example, suppose it is required to make a model for a short length of beading of section indicated by fig. 286*a*. The sheet-zinc templet will be cut as in fig. 286*b*, and this will be nailed to the wooden mount as in fig. 286*c*. The mounted templet is then fastened to a strong piece of wood at right angles to the mount, the two pieces being braced together by a strip as

in fig. 286*d*. Along the lower edge of the side-piece, on the outside, a strip of wood is nailed to act as a guide, this complete little construction being called a "horse" (fig. 286*d*).

A slate slab, about 4 feet 6 inches by 3 feet 6 inches by $1\frac{1}{4}$ inch, is fixed upon a strong, roughly made table, in such a manner that the slab projects about 4 inches over the woodwork beyond each side of the table. Upon this slab the modelmaker places the completed mount and horse, in such a position that its elongated edge, or guiding-strip or rabbet, fits along and against the edge of the slate slab, keeping the mount true when it is subsequently moved forward and backward upon the slab, as in fig. 286*e*.

Prior to putting the mount on the slab, clay is built up on the slab in a

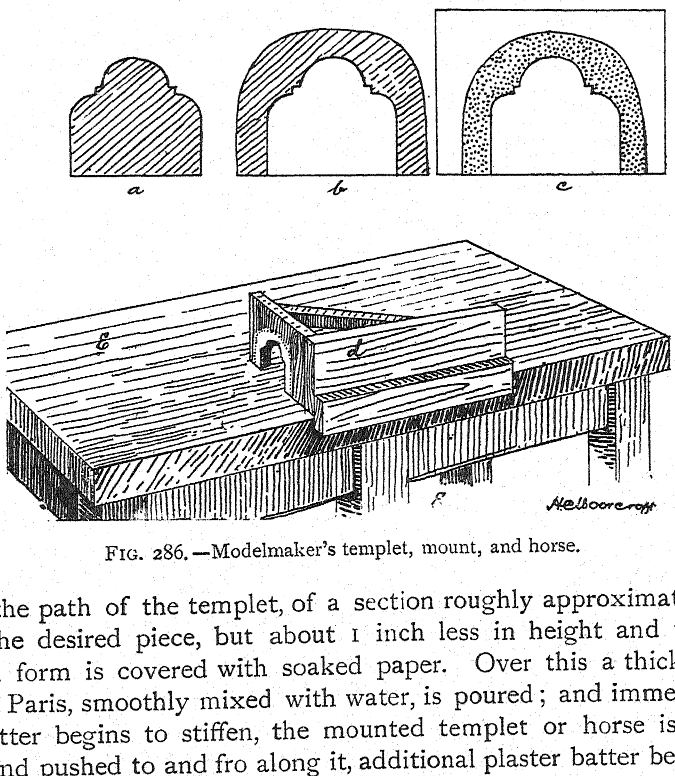
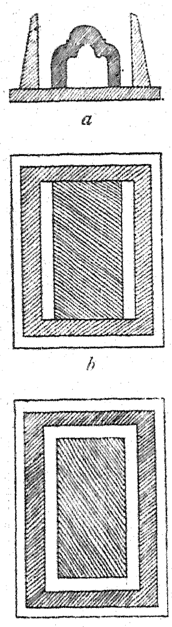


FIG. 286.—Modelmaker's templet, mount, and horse.

length in the path of the templet, of a section roughly approximating to the form of the desired piece, but about 1 inch less in height and width, and this rough form is covered with soaked paper. Over this a thick batter of plaster of Paris, smoothly mixed with water, is poured; and immediately the plaster batter begins to stiffen, the mounted templet or horse is placed in position, and pushed to and fro along it, additional plaster batter being poured on as needed until the whole form has filled up and completely fits the profile of the templet, and the desired length accurately coinciding with the profile is formed. The mount is then carefully drawn off and the plaster model cut to the length required, cutting off, of course, according to shrinkage scale, $13\frac{1}{11}$ inches for every 12 inches, or 8 inches for every 7 inches, as the case may be, in proportion to the anticipated shrinkage.

As soon as the plaster is firmly set, the model may be lifted off the clay base—the soaked newspaper facilitating this ; then, before proceeding further, the model should be placed in a drying-chamber for a short time.



a

b

c

FIG. 287.—Mould-making.

To make the plaster moulds, place the dried model on a bench and brush it all over with a parting solution (soft-soap boiled in water to a creamy consistence); then build up around the model, at a distance of 2 inches, a wall of clay or a "cottle" (see fig. 287*a*).

Pour in slowly a smooth creamy mixture of plaster in water, to the height needed to cover the top of the model to a depth of 2 inches. At this stage, with large moulds it is usual to press into the soft plaster several rods or strips of iron so as to strengthen the mould.

The plaster of Paris mixture may be made in a large vessel proportionate to the size of the mould to be run, thus :—Fill the vessel two-thirds full of warm water, then add plaster by small quantities at a time, dropping it in the centre of the water, until just a little island of dry plaster appears at the surface ; then stir this mixture until all is well mixed and free from lumps. Immediately it begins to thicken it is ready for use. When run and set the mould must be thoroughly dried before using.

Fig 287*b* indicates in plan the placing of the cottle when a mould is required with open ends, and fig. 287*c* indicates in plan the placing of cottle for moulds with closed ends.

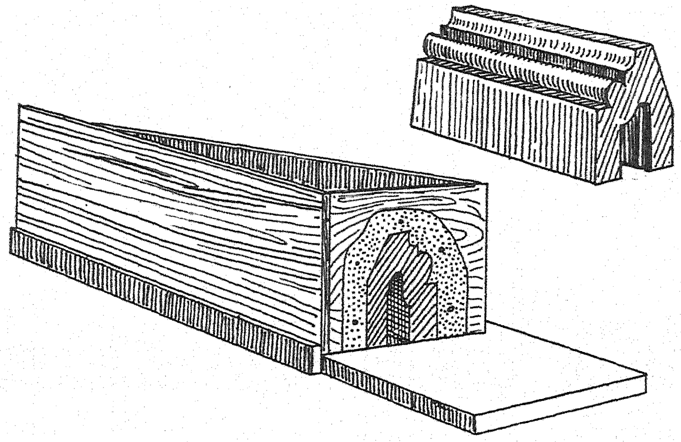


FIG. 288.—Cornice modelmaking.

A model for a cornice, such as sketch, fig. 288, say 12 inches by 9 inches

by 10 inches, or any desired size or profile, may be made by the methods indicated in the foregoing, with very few modifications.

Fig. 288 shows the templet duly cut and fixed on a mount and the mount attached to the horse, upon the slate-slab bench, ready for fixing the clay core and running the plaster.

The desired length having been run with plaster and allowed to harden sufficiently, the model can then either be cut off squarely at right angles to the length or mitred as required.

The moulds for the cornice may then be made in three parts, as indicated in fig. 289. The model being conveniently placed on a bench and sized, the loose pieces or "slips" marked S must first be run in plaster separately. These loose pieces are intended to enable the work to leave the mould easily; afterwards, the loose pieces and model being in position, they are all sized and the main case mould M run over them altogether, as shown in section in fig. 289. When set hard, the moulds may be removed and laid aside to dry.

Or the mould may be made in five parts, viz., two loose pieces, two ends, and the main case.

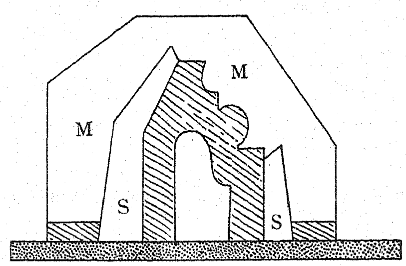


FIG. 289.—Cornice mouldmaking.

Respecting the relative proportions of cornices, Mr. Burgum, when referring to terra-cotta work, has pointed out that the length should always be greater than the height. For instance, a 12-inch deep cornice should be made in lengths of at least 15 or 18 inches. Nothing looks worse, he tells us, than 15-inch stuff cut up into 12-inch lengths. He also notes that all blocks of large projection must have a corresponding bed to balance. In all constructional work a bed of at least $4\frac{1}{2}$ inches should be allowed for building in the wall. (*Brick and Pottery Trade Journal*, March 1903, p. 118.)

When plaster models are required to furnish many moulds, they may be saturated with drying oils; and when these have hardened, the model may be sized and moulds run.

Moulds for mouldings of any section required for friezes, architraves, pilasters, jambs of doorways, etc., may be formed in the manner already described. For example, in fig. 290 the sectional moulding itself, if same profile top and bottom, could then be used either as a frieze or a pilaster, and any enrichments, other than the members of the moulding produced by the profile, being afterwards added by the artist.

To enable the modeller to put on the enrichments in plastic clay on the plain plaster model, the plaster model should be dried and varnished to prevent suction of the plaster, which otherwise would probably dry

the attached clay and shed it. For work of a very ornamental character, such as the bases of the pilasters seen in the corridor at Glasgow, fig. 291, when of considerable size, may be formed in several parts.

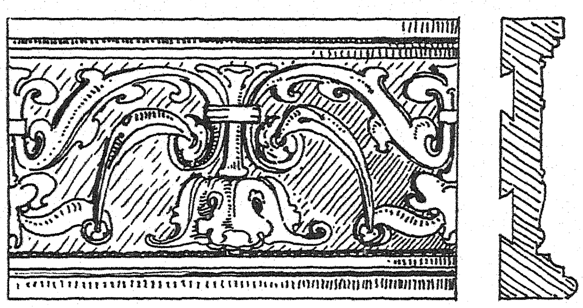


FIG. 290.—Frieze block and section.

The modelmaker having formed the plain plaster models for each separate part, according to the drawings, these parts may be fixed up together, and the plaster surfaces prepared so as to prevent suction, and the ornaments modelled on in clay, and afterwards cut across transversely, so that the sections may be taken to pieces and moulds run for them, in the manner already indicated.

Each block or part must have a $4\frac{1}{2}$-inch bed to fix in the wall.

Pilasters, capitals, shafts, corbels, etc., are all treated similarly, and the higher the relief the more complex and difficult the moulds are to make.

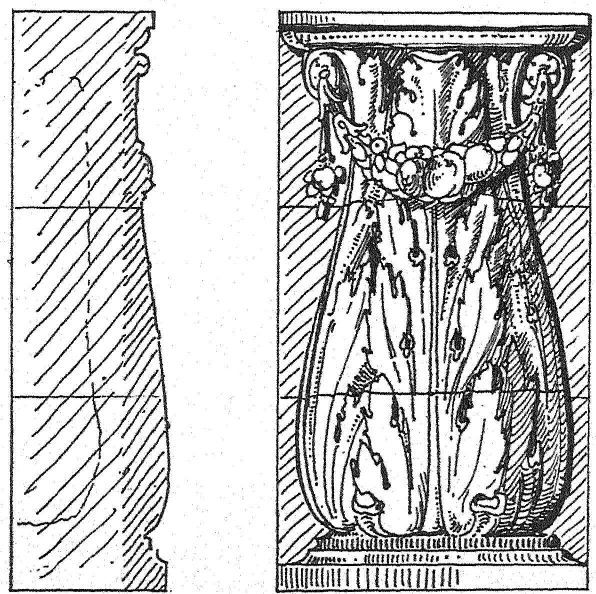


FIG. 291.—Pilaster base.

Models for curved forms, such as arched cornices, arched mouldings, or the arched mullions of tracery windows, may be made by means of a mounted templet constructed so that, when moved to and fro upon the slate slab, it will describe an arc of a circle of any desired radius. This is effected by omitting the guide-strip from the elongated edge of the "horse" or mount contrivance, and attaching a strip of wood a few inches longer than the required radius (see fig. 292); a hole bored in the strip at P serves for the pivot peg to be placed in, and so controls the movement. In the figure, A is the mount carrying the zinc templet, B the supporting piece and rest, and C is the bracing strip.

G. W. Wilson, photo.] [*Aberdeen.*

Faience Corridor,
Municipal Buildings, Glasgow.

Suppose the section of the desired mullion to be as shown in fig. 292, D. The zinc templet E is first made in the manner before described for exactly half the section, and tacked on a wooden mount (see fig. 292, F), and the whole arranged on the slate slab, and set so as to work in the path of the desired arc. The model of the half-section must then be formed in plaster, in the manner previously described for other pieces; when this has been done, each side of the mullion being identical, two pieces of correct size and length are placed together as in fig. 292, D, and moulds made in the form of book-moulds, as follows:—

Half the case is indicated at fig. 293, G, and the companion half at H;

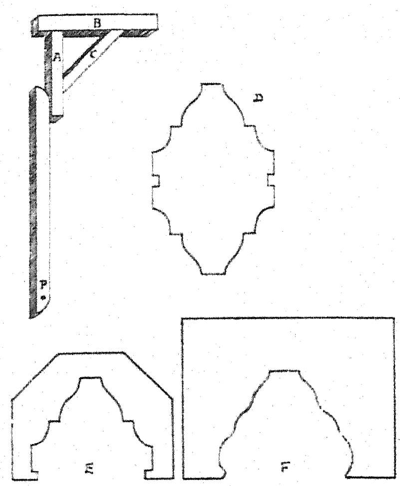


FIG. 292.—Modelmaking of curved forms.

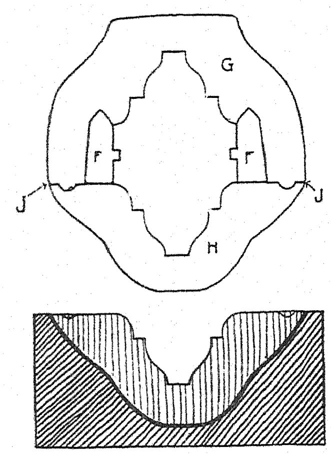


FIG. 293.—Book-mould making.

good joggles being cut in the joint J; loose pieces for easing delivery are shown at F.

To begin with, brush the model several times with parting solution (about ½ lb. of soft-soap dissolved in 1 quart of boiling water); then on the bench form a small tank or box of stiff-tempered clay, 2 inches deeper and wider inside than section H in fig. 293; pour in the plaster-in-water mixture in the cavity so formed until partly filled, then press the sized model into the semi-fluid plaster until it is as deep as joint J. When set, cut in the joggles, or use pitcher natches, size the edges and run the two loose pieces; when these are set, size and then make mould G. Or the procedure may be reversed, the loose pieces being run first, then G and then H. Or yet again, the model may be first buried up to its widest part in clay and the top moulds run first.

Models for arch-spring blocks and intersecting blocks will usually be most quickly made by running mullion pieces as already described, and then cutting up and piecing together suitable portions. This will perhaps be more

intelligible after perusing some excerpts we are kindly permitted to make from Mr. H. Burgum's contributions to *The Brick and Pottery Trades Journal* of January 1903 respecting this sort of work in terracotta.

In an article entitled "The Jointing of Terracotta" Mr. Burgum observes:—"In our last article an example was given of a tracery window showing how the blocks would repeat, at little cost, by certain jointing. The design was, of course, chosen to suit the text, to a certain extent; but so many and varied are the sorts of tracery, that arguments that apply to one would be quite out of place with another.

"Here sketches are given of two windows which appear to be somewhat alike as regards the amount of work in each. Yet in reality the cost of making BX [fig. 295] in terracotta would be double the cost of AX [fig. 294].

"In the first place, it will be noticed that three of the five openings in sketch BX differ slightly in size. In an ordinary window-head, or any straight work, an inch or two simply means a cut block, more or less, and makes no difference in price; but in tracery, or any circular work, an inch in opening means a lot indeed. All the radii begin to alter, and there is no end to the fine distinctions, without a very perceptible difference, every one of which means another model and mould.

"Not only must the number of models and moulds required be studied, but also how the models are to be made. An important point in modelmaking is to consider which model to make first, so that, when moulded, it will '*come back*,' and with some slight alteration—perhaps an hour's work—it makes another model; whereas to start and make the same without the old model (as we may call it after being moulded) would mean eight or nine hours' work and the use of more plaster. This is, of course, always supposing that the model will 'come back.' If the radius is different, the model is useless for conversion. The object of the two sketches AX and BX is to illustrate this point more clearly.

"In AX all the five openings being 2 feet, and all the centres being struck from the springing line, all the models are the same radius. If D be made first and moulded, it can be used to make F. The cusp is easily knocked off and worked on the other side, and a second time it will come back and make K, and a third time O. Not only in this way is time saved, but plaster also.

"It must be understood that model D is first run as a circular closer, and the cusp worked or stuck on not too firmly. If the cusp is run and 'let in,' which is sometimes done when large, then the model, after being moulded, requires a lot of making up; but there is no occasion for this, as it is just as easy to work or stick on as to let in.

"Model A has as much work in it as any in the whole window, but it repeats four times, and the two B's cut out of one press with no alteration.

Here we see the advantage of the section being reversible. D repeats ten times, counting the two E's, which are the same, with back or other portion of block cut away; and the same with the two G's, which cut out of F, of which there are eight repeats. Ten blocks out of one mould (in tracery) is good.

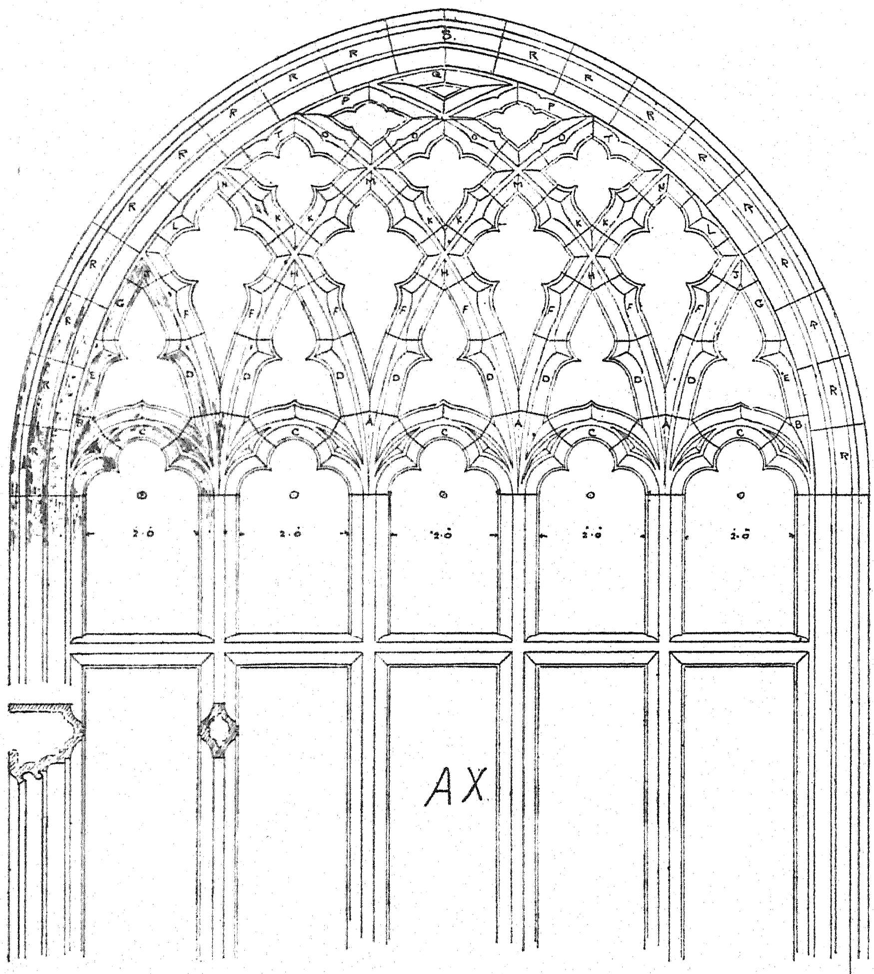


FIG. 294.—Tracery window.

The mould which makes the three H's will also make the two J's. The same applies with N's out of M, and T's out of O.

"Model M, being larger than H, is made first and comes back to make H. The two P's will cut out of Q. R repeats well, and the apex or key block S could be stuck in clay with little risk, two R's being used. Thus, with five

convertible models and ten moulds, seventy-six blocks are obtained. Now, see how window BX works out, so as to be able to compare them. In the sketch the centres are shown. They are many and varied compared with AX. These would not be seen on the sketch on a bill of quantities, nor on the tracing accompanying, for estimation purposes; perhaps not even the openings.

"The openings being different are the cause of the centres being so erratic.

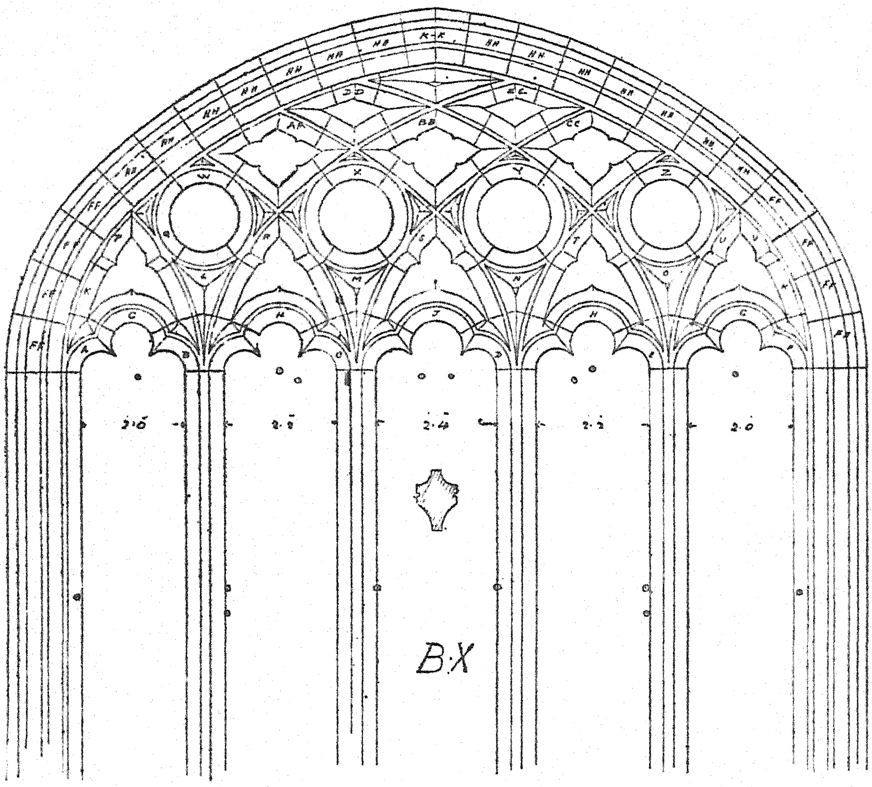


FIG. 295.—Tracery window.

In this window very few, if any, of the models will come back for alteration into other models, so at the very first there is a big difference in plaster and labour for modelmaking. G, H, K, FF, and HH are the only blocks that repeat, and the first three of these but twice, so that at the least there are required thirty-two models and thirty-two moulds to make fifty-six blocks. Yet an estimator could hardly be blamed for jumping to the conclusion that the value—or rather the cost of producing these two windows—would be about the same, because we must bear in mind these differences on the

architect's small-scale drawing would not be so glaring as in the sketch." (*Brick and Pottery Trades Journal*, January 1903; reprinted by special permission.)

In making faience for a large tracery window, such as indicated in fig. 294, the methods followed by terracotta-makers may be adopted, as far as the biscuit ware is concerned. The draughtsman, when preparing the full-size drawings for the modelmaker, drawn to shrinkage scale, must mark the sections or separate blocks with due regard to getting as many similar pieces or "repeats" as the design will allow; and where differences are unavoidable, easy alteration of model so as to "come back" must be an aim constantly kept in view.

To make models for blocks A in AX (fig. 294), and all intersecting blocks, plain closers must be run of the several different radii, and suitable parts or sections cut out from these and pieced up so as to form, when together, the model required.

Models for high-relief ornamental panels for lunettes, spandrels, entablatures, lintels, or rectangular recesses may be made by first running a slab of plaster of Paris, with any necessary moulding, in the way already described, and cutting to correct shape. This is then dried and placed on an easel, and varnished on the parts where the reliefs are required. The modeller then applies the desired enrichments in clay.

When the ornamentation is completed, the model, if of large size, is cut up into convenient-sized blocks, and so as to suit the lines of ornament as much as practicable, then raised on a bench, sized with soft-soap size, and the moulds run separately for each part.

Very richly modelled faience plaques should be modelled on a bed of clay the required shape and size, with due allowance for shrinkage. Then to make the mould a wall of clay is built around the model, and the plaster cream poured over to the necessary thickness. Two inches thick of plaster is perhaps not excessive with large pieces, and may further be strengthened by strips of sheet-iron pressed into the plaster while soft.

Faience-Pressing or Filling the Moulds.—The body-clay having been selected and prepared according to the ware required, a portion is taken in a moist plastic state, well kneaded and beaten out on a plaster slab, to a bat or clot of the proper thickness, about 1 inch or less. After seeing that the mould is perfectly clean and dry, this layer or clot of clay is put in, and pressed home well and evenly by hand, care being taken to see that every part is covered, and also well and evenly pressed in, particularly the joinings. With large moulds, successive clots of clay are laid in side by side until the whole mould is covered; these are rammed in, particularly at joinings, so as to incorporate the whole into a perfectly continuous piece. Excess clay is then cut off the edges of the mould, and the mould with its contents together placed

aside to dry in suitably heated rooms. Faience-ware is thus pressed comparatively hollow, being from $\frac{3}{4}$ of an inch to 1 inch thick of clay.

When the clayware has hardened sufficiently to be handled conveniently, it is removed from the mould, which operation is rendered the more easy owing to the slight shrinkage which has taken place during the drying.

At this stage seams of clay formed by the joining of the moulds are carefully cut away, and all irregularities removed and corrected before the ware undergoes its final and complete drying prior to burning.

In the case of plastic-made panel slabs for painting upon, Ansell suggests making the slab in a plaster mould, placing aside to stiffen; when stiff, turn

FIG. 296.—Faience-work. (*Carter & Co., Poole.*)

out on a perfectly level plaster slab, and place a weighted board upon the clay panel to keep it quite flat until perfectly dry. When burning such panels, Ansell advises setting on edge, to obviate warping. (*Manufacture of Glazed Bricks and Glazed Sanitary Ware*, p. 180, H. Greville Montgomery, London.)

Decorative Treatment in Clay State.—The application of dips or engobes to render the surface more amenable to glazing may sometimes be adopted, and by this means a comparatively coarse dark body may have a better prepared or lighter coloured surface applied, and so be rendered suitable for delicately tinted glazes, or parts only may be so treated. In any case, great care is demanded in such applications to ensure permanent adhesion, and perhaps, as a rule, these expedients are better omitted if possible.

In like manner, sgraffito, barbotine, *pâte-sur-pâte*, and vitreous colour painting may be brought into service, so as to accomplish the wishes of architects and designers. Even Wedgwood jasper ware sometimes is requisitioned, as in the case of a chimney-piece at Buckminster, one of the residences of Lord Dysart, designed by Halsey Ricardo. The elements of the most important of these processes having already been described, further reference to them here is unnecessary.

Drying Faience Clayware.—Much care and artifice is demanded for the successful drying of large pieces of plastic-made constructional faience. In the first place, the pieces must of necessity be kept level and in true form; therefore they must never be placed on uneven surfaces while in the clay state, nor upon thin boards liable to bend, nor carelessly or unnecessarily moved about.

Closed heated drying-rooms, the writer understands, are less liable to cause uneven drying, with the resulting cracking, than draughty open sheds or passages. Hence, for economical manufacture and the production of good, sound products, it is necessary to provide adequate closed drying-room.

It is also desirable to avoid a dusty atmosphere, to which may sometimes be traced speckiness not infrequently met with on faience-wares.

Setting in the Kiln.—Comparatively small pieces may be placed in saggars, and set in the kiln in the ordinary way.

Large and heavy pieces may be papered over to prevent flashing, and then set in the kiln in specially built, temporary firebrick chambers, pigeon-holed about 2 feet 9 inches or 3 feet high, floored over with fireclay slabs as successive heights are reached. This is the course Messrs. Carter & Co., of Poole, kindly inform me they adopt with large pieces, and in that way the goods can be burned in the ordinary biscuit ovens, such as that of which plan and elevation are shown in a preceding chapter.

Burning Faience.—Faience blocks for interiors, which are not called upon to bear any great crushing strains, may be burned in "easy" parts of the ordinary biscuit-tile oven, where the lowest heat is attained. In this way considerable loss in burning may be avoided, and the filling of the ovens in every available part assisted. The pieces of faience thus leave the kiln in best condition for thickly glazing, with rich, easily fusible glazes, and these show the relief modelling to advantage.

But all pieces intended to bear any of the general building weight and stress, whether for exterior or interior purposes, should be carefully burned in selected parts of the kiln and according to the nature of the clay, to the happiest mean possible for the clay, so that in use the ware may not be liable to crumble because of it having been too easily burned, nor yet to fracture or chip easily by reason of the ware having been burned until brittle.

Clays differ very much in these respects, and therefore the burning must necessarily be adapted to the particular clay or clay compound used.

It should ever be borne in mind that this first biscuit-burning imparts to the piece all the firmness and strength it will ever possess as a building material, the subsequent heating, to fuse the glazes or enamels upon the ware, being quite insufficient to increase the crushing strength of the ware, even if it does not injure this by the quick changes of temperatures during the process.

A good glazing surface must also be conserved, and the clay composition arranged so that, as nearly as possible, the pink of condition in strength is attained simultaneously with that of a good glazing surface.

FIG. 297.—Decorating. (*Carter & Co., Poole.*)

Some clays are liable to give up a surface scum or rust during drying and burning, particularly when of a too plastic and vitreous nature, and this film may cause glaze to curl off the ware; to obviate such a source of loss, the body may with advantage be varied so as to render it slightly more refractory, and perhaps a trifle coarser in grain on the surface, also to have the ware well dried and brushed before burning.

When it is anticipated that some amount of alteration may have to be made in the shape of the wares by the fixers, so as to satisfactorily form a design or an arch by use of a number of pieces, then it may be advisable to limit the degree of burning, so that the hardness may be susceptible to cutting.

Biscuit Decoration.—Obviously this may partake of any of the various modes of treatment described for the biscuit surface of tiles, such as the modified forms of barbotine, *pâte-sur-pâte*, underglaze colour painting, vitreous colour painting, "majolica" glaze painting. The whole of these processes are

at the service of the designer, but only a few lend themselves successfully to the breadth of decorative treatment required by the architectural character of faience-work such as is now under our consideration.

The methods of decoration principally adopted are painting with coloured glazes (majolica), or with underglaze colours (biscuit-painting).

Glazing and Enamelling.—The application of coloured glazes or enamels to the surfaces is undoubtedly the principal method at present in use for the colour-treatment of relief-modelled faience. Apparently this has ever been so, even from the time of Nineveh, Babylon, Ecbatana, Susa, Tell el Amarna, Tell el Yehûdîyeh; and more recently in Persia, India, Syria, China, Spain, and Italy, these widely separated countries all furnishing authentic examples of constructive or decorative ceramics very closely related to enamelled terracotta.

If the piece to be glazed is of convenient size and requires only one colour, its surface may be most expeditiously coated with glaze by partial immersion or "dipping." But often the size or shape or the number of different colours renders dipping of the piece impracticable.

Under these circumstances it becomes necessary to adopt other modes of applying the enamels, such as painting by hand, brushing, or sponging over stencils, or blowing the glazes on. This last method, Mr. Moorcroft kindly informs the writer, is only adaptable in cases where the glaze to be used is of a very weak consistency. Nevertheless, where practicable, this method of blowing glaze on is very serviceable, owing to the easy way in which the various colours can be located on the work.

The nature and preparation of the glazes recommended for these wares have been explained in Chapter XI. It only remains to point out that, with pieces of ornamental faience in which effect is obtained by coloured glazes applied to relief-modelled surfaces, the softest or most easily fusible glazes may not always be best. On a flat tile surface, which may be placed in a horizontal position during burning, easily fusible glazes are often eligible; but with faience, which often presents several glazing surfaces at different angles, such glazes might run off portions too readily while burning; hence for constructional chromo-faience work of irregular form the glazes should not be excessively fusible.

The use of somewhat "harder" glazes may also help in partially overcoming crazing tendencies, and so be a means of producing intrinsically better ware.

Glost-Firing.—Tiles, constructional faience, and bricks, when glazed with rich, soft, easily fusible "Palissy" or "majolica" glazes, are usually fired in muffled kilns, such as have been described in a preceding chapter.

By certain arrangement in the kiln, an assortment of all these goods may, when desired, be burned at the same time. But perhaps the most satisfactory

and successful proceeding is to burn each group or class in separate kilns or at different times.

For pieces of applied or constructional faience, it is advisable to increase the fires more gradually than in the case of glazed tiles, and to maintain the heat about twelve hours longer than for ordinary "majolica" or "Palissy" tiles—this with the object of avoiding splitting the ware by either too rapid heating or too rapid cooling; although in the matter of cooling some risks must necessarily be taken, because of the equal importance of avoiding injury to the glazes by too slow cooling.

Sorting; Stopping; Retouching. — Under this heading Mr. Harold Moorcroft has supplied the following practical directions:—

"*Sorting.*—The ware should receive every attention when in the biscuit state. Details of architectural work, such as arches, jambs, etc., should be laid out in their entirety, and checked with the sizes specified on plan, in order that any unevenness which may have occurred during manufacture owing to bad fettling or irregular firing can be corrected by grinding and refitting.

"*Stopping.*—In case some important piece is what is termed 'fire cracked,' it is usual to fill up the crack with stopping to obviate the defect when glazed. This stopping material consists of the finely ground pitchers of the body being dealt with and water, mixed to a nice plastic consistency. To obtain the best results, previous to applying the stopping the ware should be damped. The aperture should then be filled up and finished by means of a palette-knife or a piece of wood. The glaze should be applied as soon after the above process as possible.

"*Retouching.*—It often happens that, on the ware attaining the glazed state, certain pieces come out faulty, owing to the glaze having run very unevenly, and therefore showing light patches. This can be adjusted to some extent by mixing a little more stain to the original glaze, and painting it on the light parts, and then to redip the piece in the original glaze."

Fitting and Proving.—Continuing, Mr. Moorcroft states, with regard to dispatch of the finished wares:—"It is always advisable to fix as much of the ware out as possible before sending away, and to number the pieces in their respective order to facilitate fixing; that is, when the portions being dealt with are somewhat complex or intricate."

Decoration on the Glaze.—In this matter the writer is indebted to Mr. H. Moorcroft, of Wolstanton, for the following notes:—The application to faience-ware of decoration on the glazed surfaces is of rare occurrence, owing to its susceptibility to the reducing effects of the atmosphere, particularly in exterior work. Yet in the latter case, where bright colours (which are unobtainable under the glaze and by tinted glazes) are necessary, it is advantageous to be able to resort to the lustrous effects and rich palette at the disposal of the artist when concerned in the decoration of glazed ware.

Nevertheless, such decoration, unless imperative, should always be avoided in exterior work. For interior decoration, mainly basements where artificial lighting plays so great a part, the decorative treatment of capitals and ornamental relief-work, by lustre and rich colour, are often matters of considerable importance to the architect and designer.

Genuine lustre can result from an irregularity of the glazed surface, caused by decay, shown in the form of a beautiful iridescence, but those referred to above are applied to the ware as paint.

These lustres (which consist of metallic salts, such as those of copper, bismuth, gold, silver, iron, and platinum, mixed with a strong reducing agent) are fired in an atmosphere which reduces the salt and causes the metallic film to be fixed on the ware.

The famous red lustre seen on Gubbio ware is due to the action of smoke from some burning material, such as brushwood, on the cupreous oxide, and is usually applied to a coloured body.

The use of on-glaze colours to the ware is the same as mentioned in a preceding chapter.

Fixing.—Without professing to offer full directions for fixing faience, a few gleanings of good advice from here and there may be worth noting.

For instance, a hint may be taken from the remark by Mr. H. Stannus when discussing a paper on sgraffito, read at the Society of Arts by Mr. H. Sumner on 10th February 1891. As a fundamental axiom, Mr. Stannus advised that "The wall should be well settled before the work was begun, otherwise it would be almost certain to crack and spoil the design." (*Jour. Soc. Arts*, 13th February 1891, p. 233.) Tile-fixers should take note.

At the same place Mr. Heywood Sumner, referring to the occasional failure of sgraffito owing to damp walls, said:—"I believe there is no method of wall decoration that will stand unless you first make sure of a dry wall." (*Ibid.*, p. 231.)

Mr. C. Baskett has related similar experience in the decoration of a damp church wall being destroyed in a few months. (*Jour. Soc. Arts*, 28th March 1902.)

CHAPTER XV.

COLOUR, DESIGN, DRAWING, AND ESTIMATING.

CONTENTS.—The need of colour—Light and colour—Complementary colours—Tints and shades—Decorative colour schemes—Colour in architecture—Design—General principles—Pictorial—Symbolism in design—Designing for tilework and faience—Drawing—Estimating.

FIG. 298.—From *Proverbial Philosophy*. (*By permission of Ward, Lock, & Co.*)

WHEN a knight of the order of Art, such as Sir W. B. Richmond, A.R.A., asserts that "Colour and form can no more be described in words than notes of music" (*Jour. Soc. Arts*, 21.6.1895, p. 716), amateurs surely need to ponder over their effusions before venturing to commit them to print.

However, as no originality is claimed for the contents of this chapter, the material of which has been drawn from well-known sources, the ideas expressed may possibly be of service to those who have not gone over the ground before.

The Need of Colour.—Why do we desire colour? It does not feed or clothe or shelter us, except in a very abstract sense, yet it is obviously a human need, instinctively sought and cherished. It certainly helps us to distinguish and identify common objects; but, more than that, colour undoubtedly touches a sensitive chord of our nature in a delightful manner, which we cannot advantageously neglect or forego.

What a tonic a bright blue sky is to the average Britisher after a week's murky weather! Even the pessimist revives under its magic spell and permits a cheery "good morning" to supplant the accustomed growl.

Nor should the wealth of pleasure proverbially afforded by lovely flowers be measured by fragrance alone; their colour, too, appeals to old and young alike, in cottage or mansion, by the bedside of the invalid as to the ruddy child who delights to strip the verdant hedgerow of its blossom.

With regard to colour in architecture, "For half the year," says Halsey Ricardo, "our city is the colour of a dirty cobweb, and the only refreshment the eye gets is in the glimpses of the sky overhead, the shop windows, and the hoardings. . . . . We want colour in our streets; we have tried for it by using coloured building material, paint, creepers, and flowers in window-boxes . . . . but these ventures are generally disconnected attempts, and so are on too small a scale to make any distinct effect. . . . . Why not plate your building with tiles? . . . . no other surface wears so well. Stone perishes rapidly. Bricks and terracotta get incurably befouled. Marble requires frequent repolishing. Granite endures, but unless it is polished it also gets filthy. But a good glazed tile, glazed brick, or faience should be as durable as a plate-glass window, unaffected by the wildest acids that infest our atmosphere. . . . . As to our public places, take Trafalgar Square, for instance. At present it is an arid waste, grey and ineffective, with various disconsolate, grimy, black statues. . . . . Let us imagine it taken in hand and made to serve some pleasant and useful purpose, and so far as we can, beautiful. We will begin by reducing the inordinate size of the basins to the fountains and lining them with turquoise-blue tiles, and by stipulating that for the future the fountains shall spout clear water." (*Jour. Soc. Arts*, 24.1.02, pp. 163-4-5-6.)

An equally vigorous appeal for more colour was made eight or nine years ago by "Hermes" in the *Architect and Contract Reporter* of the 2nd February 1894. "When, as of old, shall we see the glory and the charm of colour in our external architecture? About a year ago a dozen leading men joined together in writing a book claiming modern architecture as an art, yet I believe that not a word was said about colour, perhaps for the very simple reason that nothing can be said of what has no existence; but I make bold to say that if this beautiful and never-wanting characteristic of ancient architecture could have been claimed by one or more of these eloquent writers as distinguishing the art of these days—well, the book need not have been written.

"Architecture with colour is, or may be, a fine art; without it, only a science, a practical art, a business or a profession. . . . . Once upon a time, and for centuries of time, there was scarcely such a thing as architecture, external or internal, without rich colours. Harmony was secured and vulgarity avoided by the fearless use of at least two colours associated with black and white. People in those days would have been as surprised to see a monotone building of any more importance than a labourer's cottage, as to see a leopard without his spots, a tiger without his stripes, the

trees all grey, or that for some unaccountable reason the allwise Creator had changed 'polychrome moths, humming-birds, gold-fish, roses, and violets into one uniform tint.' So essential was colour in the opinion of the Athenians that they treated the beautiful marble of Pentelicus in their temples very liberally with it. If, then, the above architects still find any difficulty in convincing the British public . . . . that they are artists first and practical or professional men afterwards—that they really understand architecture as a fine art, that it is something more than a business—let them at once take vigorous measures, by establishing a society of painter-architects or otherwise, so that our thoroughfares shall . . . . display the ancient necessary and lovely art of external polychromy. I am aware that men who never had a brush in their hands, or who by nature have no eye for colour, tell us that our dull and changeful climate is opposed to this idea. I venture to say . . . . that paucity of sunshine is a reason not for the monotonous treatment of architectural façades, but for the boldest polychromatic effect, like that adopted in . . . . Auvergne . . . . in Bavaria . . . . and in Munich, where colour is at this day a striking characteristic of modern external architecture." (*Architect and Contract Reporter*, 2nd February 1894.)

Light and Colour.—Colour having no existence for us in the absence of light, and the eye being our only means of appreciating the phenomena of light, it follows that any scientific study of colour must include the study of optics and light. These subjects are out of our province, but it is obvious that everything we see is visible only by reason of its reflection or emission of light. It was Sir Isaac Newton, we are told, who discovered that white light is compound and capable of separation into constituent colours. He demonstrated this by passing a ray of solar light through a flint-glass prism, arranged in a certain position, when, on account of dissimilar refrangibility of the component rays, a band of rainbow colours is produced on the screen; this band of colours is called the solar spectrum, and the coloured lights so produced are the purest with which we are acquainted. Selective absorption of these rays of light by the objects that come under our notice thus plausibly accounts for the phenomena of colour.

Yet as to the real nature of colour even experts cannot agree. Hay, in 1847, with all his experience and acumen, regarded the laws relating to colour phenomena as well known and scientifically established; nevertheless, long afterwards, Professor Church, in his profound knowledge, confessed that the theory of colour is still merely a provisional one. (*Cassell's Tech. Educ.*, vol. i. p. 395.)

"The colour of an object," says Captain Abney, "depends on the composition of the light falling on it, on the material on which such light falls, and on the eye of the person." In his *Cantor Lectures* he proceeded to explain and demonstrate that our appreciation of the compound nature of

white light arises from the action of three sets of nerves in the human eye, one responding to red, one to green, and another to blue.

But whatever the physiological reasons, it is found practically useful to assume the existence of three primary colours from which other colours and hues may be composed. Unfortunately, the selection of these three primaries is far from unanimity even among distinguished scientists: one set of observers choosing scarlet, green, and blue; another choosing red, yellow, and blue—Chevreul, Field, Redgrave, and Hay accepting the latter; while Maxwell, Benson, Church, and Abney favour the former as being more in accordance with results of researches upon the pure colours of the solar spectrum. Professor Church even ventures to express surprise that authors of nearly all the manuals of design and colour, as applied to the decorative and fine arts, should appear to be so ignorant of the more correct views as to invariably adopt the more commonly received theory, which, whilst working well with actual pigments, breaks down when tested with coloured rays of light.

Other points observed by specialists are: (1) that colours are subject to ocular modifications in the same individual; (2) that different individuals have different powers of appreciating colours; and (3) that, though form can exist independently of colour, it never has any important development in decorative schemes without the chromatic adjunct.

Indeed, colour alone seems to have greater charms than form alone. What is a mass of angry clouds compared with a cloudless sunset, when the whole fleckless sky glows with the entrancing radiance of colour—one lovely tint merging imperceptibly into another, or changing, chameleon-like, into successive hues as the sun appears to descend lower and lower below the horizon? Who could depict such a glorious sunset in black and white? In the presence of light, colour becomes one of the most evident manifestations of nature. Instead of minerals, vegetables, animals being of one monotonous neutral tint, everything is diversified—a ruby, a pearl, a fire-opal; a primrose, a bluebell, a holly-berry; a peacock, a leopard, a gold-fish; a leaf in spring, the same in autumn!

But colours are observed to only please and satisfy the educated eye when associated or arranged harmoniously, and this largely apart from individual likings and antipathies; for, although some may delight in gay colouring and others in deep, grave, complex arrangements, there yet appear to be discordant arrangements of colours not pleasing or satisfying to any appreciative person.

In music each variety of style and composition has its individual admirers and devotees, but it does not follow that the notes of a melody are matters of mere caprice—this could only produce jargon.

So, with reference to colours, if harmoniously arranged, the effect will be

pleasing; while if not so arranged, it usually proves displeasing. The Egyptians and the Romans are both said to have left evidences of their regard for and attention to these laws of applying colours.

Complementary Colours.—Buffon observed that, if we look steadily for a considerable time upon a spot of any given colour, placed on a white or black ground, it will appear surrounded by a border of another colour; and this colour will uniformly be found to be that which makes up the harmonic triad. For if the spot be red, the border will be green; and if yellow, the border will be purple; and so on. Thus, blue, red, and yellow are by some supposed to be the primary colours. By combination of any two of these, a secondary colour of a distinct kind is produced; and as only one absolutely distinct denomination of colour called a hue can arise from a combination of the three primaries, the full number of really distinct tones is seven. Each of these is capable of forming a key or tonic for an arrangement to which all the other colours introduced must refer subordinately. This reference or subordination to one particular colour or hue gives a character to the whole, just as a key-note in music.

Tints and Shades.—According to Hay, there are only three classes of colours, viz., primaries, secondaries, and tertiaries or hues; a primary colour being inseparable into parts, but reducible to a tint by white, or to a shade by black, or to a secondary colour by either of the other primary ones. A secondary colour is produced by the combination of two primary colours, such as orange from red and yellow, purple from red and blue, or green from blue and yellow; and these secondaries may be reduced to tints by white, or to shades by admixture of black, and may also, by the subordination of either of their components, be changed in tone. A tertiary colour or hue is compounded of two secondaries, and is consequently a mixture of three primaries; it may therefore be modified in tone very greatly.

Black and white form a perfect contrast to each other, and being the extremes of light and shade they impart this quality to the colours with which they are combined.

A tint is not a specific colour or hue, but one of the gradations of any colour or hue from its most perfect state of intensity towards white.

A shade is one of the incalculable gradations of any colour or hue from its most perfect state of intensity towards black.

Decorative Colour Schemes.—For decorative purposes there are very great advantages in thus introducing system and classification of colours, so that those who possess no intuitive genius in the direction of colour harmony may yet be enabled to manufacture and apply their products intelligently, and so as to give satisfaction to their clients. This is of vastly more importance in the case of ceramic works than of wall-papers, wall-paints, frescoes, carpets, linoleums, oil-cloths and the like, because of the greater

permanence of the former. For this reason, immense responsibility must burden a sensitive mind charged with the ceramic decoration of an important public building.

The frankness and publicity with which Sir W. B. Richmond has expressed his feeling with regard to the glass mosaics in St. Paul's Cathedral probably reflect in a great measure the thoughts of many an architect as he critically examines and reviews his designs for wall-tiling and faience when *in situ.* Only the architect knows what effects he desired to produce; he only knows how much short of his aspirations is the reality. It is often perhaps better that others should never know the height of the ideal as it was formed in the conceptions of the architect. Let the designer bear his discontent in silence; others may be perfectly satisfied with the actualities, and to impart discontent would do them a useless and undesirable injury, and impair their whole-souled delight and gratification in the work.

Nevertheless, for the practical decorative ceramist and architectural designer, Sir W. B. Richmond's criticisms of his own work (see *Journal of the Society of Arts*, 21st June 1895) are a mine of wealth. "Every portion of a building," he says, "requires a different treatment, owing, of course, to the manifold effects of light to which surfaces are subjected. . . . . The practice of painting the decoration in the studio and clapping it upon a wall, differently lighted and differently influenced by the character of architectural mouldings and surroundings, is a mistake. I defy any artist, even of the greatest experience in decoration, to calculate his effects so minutely in a well-lighted studio as that his work shall appear in its proper relation to the objects which should be at once a part of it when placed in an entirely different lighting, and all the conditions of environment are totally changed; nor do I think that anything but the roughest sketch for colour is desirable for the cartoon. Although every boundary line between shadow and shade, shade and light, should be very clearly defined, because the transposing from one material to another involves changes that can only be made under the eye of the artist himself. It is true that he can calculate roughly for the modifications a necessary part of transposition, but the more delicate modifications, which are the life and soul of success, he can only make when actually working in the material that is ultimately to produce his design; and for this reason it is necessary that the artist should be constantly upon the spot, watching the translation of his design from one material into another whenever he cannot execute it himself." (*J.S.A.*, 21.6.95, p. 724.)

The manufacturer of decorative faience, however, stands very much in the position of the colour manufacturer or the house-painter. He has clients of all kinds to please, and his products are liable to be placed by one client in a dark position, and by another in a full light; therefore the colours employed should, as Hay states, "be toned in themselves, to prevent that

unnatural crudeness so annoying to the eye. . . . . I do not mean by this," he continues, "that bright and vivid colours are always offensive. I have already said that they add richness and grandeur, when used in their proper places and in proper quantities; but they should by no means cover the floor or walls of an apartment unless under very peculiar circumstances. . . . . Who ever saw in a work of merit the colours on the wall or carpet . . . . making a monopoly of attraction, and causing those upon the figures and furniture to sink into insignificance?" (*Internal Decoration*, pp. 56–58, Blackwood.)

Again Hay writes:—"I have asserted that a want of knowledge, or general negligence of the rules of harmony, is the cause of our errors in decoration and manufactures; and this fact is still apparent even in regard to our most splendid habitations and palaces. . . . . This does not always proceed from the painting alone, but from a want of unison between it and the furniture; for each may be perfect in its own way, and yet the harshest discord exist between them. . . . . When there is no particular tone or key fixed on for the colouring of an apartment . . . . and the painting done without any reference to the furniture, discord is generally the result. . . . .

"A second and more common fault is the predominance of some bright and intense colour, either upon the walls or floor. It is evident that the predominance of a bright and overpowering colour upon so large a space as the floor or wall of a room must injure the effect of the finest furniture.

"A third error is introducing deep and pale colours, which may have been well enough chosen with regard to their hues, but whose particular degrees of strength or tint have not been attended to. Thus the intensity of one or more may so affect those which they were intended to balance and relieve as to give them a faded and unfinished appearance. This may proceed from applying the general laws without any regard to the more subtle principles of the art; for although it is always necessary to subdue and temper such colours as are introduced in large quantities, yet when they are reduced by dilution alone the effect cannot be good. . . . . A pale tint of blue is often introduced as an equivalent to the richest orange colour, and sometimes a small portion of lilac, one of the lightest tints of purple, as a balancing colour to a quantity of the most intense yellow. This is inverting the natural order of colours altogether. . . . ." (*Ibid.*, pp. 58–61.)

But it was Dr. Ernest Hart who seemed to put all this most sweetly, when he spoke of the "tender harmony of colours that cheers but never fatigues the senses." (*Cantor Lectures on Japanese Art Industries*, p. 12.)

Colour in Architecture.—The truism that "Decoration should emphasize form" has been in one way or other frequently asserted; the particular phrase is that of Professor Binns, applied in his case to vases and the like, but it is equally applicable to architecture.—"Decoration should emphasize form."

Mr. J. D. Crace, in discussing Mr. G. C. Horsley's lecture on "Structural Colour Decoration," had apparently this axiom in mind when he observed that "It matters little to the effect of a building (as architecture) whether the wall-paintings represent the 'Siege of Troy' or the 'Jubilee Procession,' or whether either be painted in 'tempera' or 'true fresco'; but it matters everything whether these works are placed so as to make the columns look thin, or so coloured as to disturb the perspective, or so isolated as to remain disturbing patches. It is of much more consequence to the architect that the general scheme of colour should be founded on recognition of the structural lines, that the colour values should be in their right places, and that the borderings and other ornamental features should be arranged, not with a view of 'breaking up the wall surface,' but with careful consideration of their effect in expressing or explaining the surface, and in assisting the perception of structure. So far as it does this, colour glorifies a building." (*Jour. Soc. Arts*, 28th March 1902, p. 440.)

Again, in his presidential address on "The Coloured Decoration of Architecture," read before the Incorporated Institute of British Decorators at Painters' Hall, 7th June 1900, Mr. J. D. Crace observes:—"In the course of more than forty years' practice of the art of coloured decoration . . . . some thoughts, opinions, and facts have, as might be expected, been borne in on me with such recurrent force as to convince me not only of their individual importance to success in practice, but of their affording a groundwork of rules or laws, the observance of which tends greatly to simplify the complex nature of the problems presented to the decorator." Among other things he tells us that "It can hardly be too often urged that the decorator stands in a very different position towards an interior which can claim some architectural effect, to that which he occupies towards a room devoid of architectural treatment. In the latter case he is at liberty to deal with it as so much surface, free from obligation except such as his client may choose to impose, or he may himself feel it desirable to adopt. But it is quite otherwise when he has to deal with a structure which presents characteristic forms and features expressive of constructive intention. He has, then, the obligation of carefully studying the architectural expression of the structure, of ascertaining which are the features which best assist that expression, and then of weighing the proper amount of emphasis to be given by colour. All this part of his task is almost entirely independent of the consideration of any particular scale or scheme of colour. It is not at first a question of this or that hue: the first step is the complete recognition of how the *values* are to be distributed (apart from hue), and where the eye shall be encouraged to recognise promptly the form; in fact, to decide what shall be explained, as essential to the sense of stability, and what shall receive the charm of interest or mystery.

"Now I should like to insist here . . . . that the first and most necessary

condition for the intelligent appreciation or enjoyment of any building is an almost instantaneous recognition of its structural form. It is this which produces what we rightly term the quality of 'repose' in a building, that most essential of all the qualities which constitute what is admirable in architecture. Do not think that repose is therefore only to be attained by omitting all ornament: far from it. Many a noble building is full of detail with no loss of repose. It is only requisite that the structural forms should impress the mind before the ornamentation; then it matters not what labyrinths of detail or what profusion of interest are provided, they but enhance the beauty. . . . .

"What a power for good or evil is colour in a building! Properly used, it can help or supplement the architecture. . . . . On the other hand, when applied without due consideration, it may entirely disturb proportion and repose, or subvert the whole intention and effect of a fine composition. . . . . For good or evil, colour is a power. Let it be wielded with care and with due sense of responsibility. Then if the skill be there, he who wields it shall seem to possess indeed the magician's wand." (*The Coloured Decoration of Architecture.*)

Some particularly practical suggestions as to what is desirable in the decoration of buildings are to be found in A. Lys Baldry's *Modern Mural Decoration.* Respecting domestic decoration, he tritely remarks:—"The ornamentation of a house has to serve as a sort of background to the lives of the people who occupy the rooms, and it ought therefore to have a quiet appropriateness and a decorous reserve. . . . . In a really well-decorated house the ornament, as such, should never make its presence felt; it should produce an agreeable atmosphere of artistic refinement, perfectly equable and consistent; but the observer, unless he sets himself deliberately to analyse the means by which the effect is produced, should not be conscious of the various details. . . . . He should feel . . . . sufficient contentment with his surroundings to be disinclined either for analysis or inquiry. It is by this power to suit itself to different moods that the adaptability of a decorative scheme to the necessary conditions of domestic work can best be estimated. Its reticence is the source of its success." (*Modern Mural Decoration*, p. 169, Newnes.)

Of public buildings Mr. Baldry speaks with equal light and leading. "In a public building . . . . with its more ample proportions and greater spaces, a richer and more sumptuous style of adornment is permissible. . . . . The decoration can be made more obviously independent as an artistic effort, and need not be so strictly considered as a background. But the artist is not by this enlarging of his scope relieved of the obligation to keep all the parts of his work in proper harmony. In a sense, perhaps, his responsibility is increased, for he has to deal with bigger masses and more definite effects, and is exposed to serious temptations to run into extravagance. The delicacy of

touch and feeling which would give an exquisite daintiness to an ordinary room would make a public hall or theatre seem blank and colourless; the relative scale would be wrong, and the absence of right proportion would be unpleasantly perceptible.

"Out of the consciousness that this weakening of the decorative effect is always possible when large surfaces have to be covered with ornament has come quite a crop of failures. So many men who could manage a small undertaking tastefully . . . . have gone hopelessly astray in the attempt to succeed with something more ambitious. In their desire not to be trivial they have run to the opposite extreme, into fussy exaggeration and reckless want of balance. . . . ." (*Modern Mural Decoration*, p. 170, Newnes.)

With more especial reference to exteriors, particularly those of considerable architectural and national pretensions, the strictures by Mr. W. Fred upon the Paris Exhibition buildings of 1900 are very instructive. To use his own words:—"With a building the element of formative art must be the strongest, and not that of beautiful, or rather beautifying art. All beautifying belongs to the sphere of ornament, and therefore a house front must offer more than the impression of a well-ornamented plane or relief. Nothing could be more completely wrong than that kind of building-front which aims at pictorial effect and at destroying the impression of the house by all kinds of ornament. The best front is the one which offers the clearest, most decided expression of the whole building in its exterior and interior construction and in its purpose. And that has here been forgotten; all impressions are produced sooner than architectural ones—ornament alone has been considered by the builders of the exhibition palaces. . . . . Every gate, every colonnade, every bridge, every wooden decoration was to show many *ideas*. And in hunting for arabesques for ornament, for pictorial in absence of architectural ideas, the builders have lost every feeling for the limitations of formative art. Unbearable haste and nervous excitement mark all the buildings that have a decided exhibition character.

"The two art pavilions destined to survive the summer, and therefore not really belonging to the architecture of the exhibition, have to be excepted from this general condemnation. Their architects, and those of the Pavilion of Horticulture, have kept away from the ornamental rage to which all the architects have succumbed. The visitor's sufferings commence already at the first gate. The much discussed Porte Monumentale by Binet is an example. . . . . Out of the many ornamental details which are disconnected, their home being partly Assyria, partly a misconceived Paris of to-day, a gate is formed which has no effect in daylight, in spite of the variegated but weakly colours; whilst under the artificial light in the evening, the separate effects of the different parts produce hopeless confusion."

As to some of the frescoes, he wrote:—"The eye finds no point of rest on

this front. It is forced up and down, to the right and to the left. Countless plaster cupolas, special façades, and statues have been added on all storeys and on the roof. That coats-of-arms and emblems and modern line decoration are not absent is only natural if one bears in mind the decorative mania of the architects. Everything is to be effective—except the plane. By this method the architects and builders—Larche, Nachon-Tropey-Bailly, and Esquié—have lost the effectiveness from the distance which they certainly ought to have borne in mind. But the many details get blurred if one only steps back a little, and the only impression is one of confusion. . . . ." (*Artist,* July 1900.)

Similarly, Halsey Ricardo tells us that "pastry-cook architecture" won't do for exteriors. "The colour," he says, "must be laid on in a broad bold mass, and pattern used only sparingly, if at all. The windows and other openings should occur in a field of plain colour, or some simple chequer or trellised diaper, and the limits of the tiling should be bounded by bands and trimmings of glazed terracotta." (*Jour. Soc. Arts*, 24.1.02.)

There are, of course, differences of environment calling for different treatment; for example, an erection on the Thames Embankment, with a principal façade toward the river front, necessarily requires, or at least is susceptible of, very important variations from styles suited to the front of a building in a narrow thoroughfare. So also an exterior in a manufacturing town as compared with an exterior in a spa or watering-place. Thus arise demands for ample variety in ceramic manufactures for architectural purposes.

Fashion.—Another influential factor manufacturers have to reckon with is fashion, for this is the root-cause of many public demands, and the manufacturer who is best prepared to supply fashionable goods is the one to whom it may bring both fame and fortune.

Whatever views of an ethical nature a designer or a manufacturer may hold as to the wisdom of yielding to fickle fashion, there is certainly, from a purely commercial standpoint, only room for one opinion.

Long ago Passeri deplored the fact that Italian majolica, which had served the table of kings and embellished temples, had become, even in his day, merely an object of curiosity sought for only by collectors. Every industry is alike; we wear fashionable boots, fashionable clothing, and even take fashionable medicine, or accept a fashionable faith.

The supposed laws of utility and beauty may have, in our opinion, to be transgressed in conforming to fashion; but for all that, a manufacturer must bow to it, and his designs must be carried out with due regard for it, if he would succeed, for there is practically no appeal from fashion's law.

Yet what is fashion? In the *Architect and Contract Reporter* of 16th June 1899 a writer endeavours to analyze it and discover its real nature. To quote his own words:—"Fashion may be considered in general as the custom of

the great. It is the dress, the furniture, the language, the manners of the great world which constitute what is called the fashion in each of these articles, and which the rest of mankind are in such haste to adopt. . . . . Whatever the real beauty or propriety of these articles may be, it is not in this light that we consider them. They are the signs of that elegance and taste and splendour which is so liberally attributed to elevated rank; they are associated with the consequence which such situations bestow, and they establish a kind of external distinction between this envied station and those humble and mortifying conditions of life to which no man is willing to belong. It is in the light, therefore, of this connection only that we are disposed to consider them. . . . . As soon, however, as this association is destroyed, as soon as the caprice or inconstancy of the great have introduced other usages in their place, our opinion of their beauty is immediately destroyed. The quality which was formerly so pleasing or so interesting in them, the quality which alone we considered, is now appropriated to other objects, and our admiration readily transfers itself to those newer forms which have risen into distinction from the same cause. The forsaken fashion, whatever may be its real or intrinsic beauty, falls for the present at least into neglect or contempt. . . . . A few years bring round again the same fashion. The same association attends it, and our admiration is renewed as before. . . . . A plain man is incapable of such associations, a man of sense is above them, but the young and the frivolous . . . . are apt to lose sight of every other quality in such objects but their relation to the practice of the great." (*Architect and Contract Reporter*, 16th June 1899.)

Design.—Notwithstanding Halsey Ricardo's dictum that "the glory of a tile is its colour," and that "the pattern is little more than a set of pegs on which to hang these colours," there are probably few useful arts in which a knowledge of the principles of design is more essential. The responsibility arising from the permanence of the work is very great: every colour scheme and every ornamental conception must be considered in that aspect. Of course, inappropriate work, if unendurably out of harmony, may be taken down again and replaced; but what architect or designer or manufacturer will lightly or intentionally run the risk of such ignominy and expense?

For a decorated tile is not necessarily a decorative one; to make it decorative something more is needed, namely, preconceived arrangement, purpose, *design*. An indefinite purposeless pattern is hardly a design, for design should consist, not merely of the impress of mind on material, but a valuable enhancing impress, such only as the mind both intuitively artistic and well stored with knowledge is capable of imparting.

One would think that the bewildering variety of designs and styles already on tile manufacturers' illustrated sheets were enough, and that no more need be said about the matter; and so in reality they are. But some-

how novelty has a commercial value, and sometimes appears to reap a disproportionate reward; hence it becomes desirable to review a few fragments of what has been written and said on the subject to help us to discriminate between good and bad, or at least between the probably saleable and the probably unsaleable.

Respecting the acquisition of practical ability in designing, Dr. Dresser expresses his belief in mathematical progression, proportionate to the work a man does at the subject; *i.e.*, he believes that, as a rule, the man who works eighteen hours a day will progress in such ability three times as fast as one who works six; and he avows he can recall instances of some upon whom nature appeared to have lavishly bestowed her art gifts, yet who were ultimately left in the rear by others less gifted naturally, but who pursued their studies more industriously.

General Principles of Design.—Under this heading are compressed, as concisely as possible, some excerpts from Dr. Dresser's papers in *Cassell's Technical Educator*, which appear to express in concrete form serviceable principles.

(1) "The first aim of the designer of any article must be to render the object which he produces useful. . . . . It matters not how beautiful the object is intended to be, it must first be formed as though it were a mere work of utility; and, after it has been carefully created with this end in view it may then be rendered as beautiful as you please."

(2) "The material of which an object is formed should be used in a manner consistent with its own nature."

(3) "Proceed as an artist and not as a mere workman. . . . . Think out an ornamental scheme and then try to realise the desired effect."

(4) "A principle of order must prevail in every ornamental composition. . . . . If plants are employed as ornaments, they must not be treated imitatively, but . . . . conventionally."

(5) "Curves will be found to be beautiful just as they are subtle in character; those which are most subtle in character being most beautiful. . . . . Proportion, like the curve, must be of a subtle nature."

(6) "The repetition of parts frequently aids in the production of ornamental effects."

(7) "Alternation is a principle of primary importance in certain ornamental compositions."

(8) "I must object to all imitations, as sham marbles, granites, etc., for no wall can be satisfactory which is to any extent a display of false grandeur."

(9) "All walls, however decorated, should serve as a background to whatever stands in front of them. Thus they must retire even behind the furniture by their unobtrusiveness."

(10) "What looks well in a pattern book may look bad on a wall."

(11) "Clay of good natural colour is not a thing to be hidden nor ashamed of. . . . . We do not use coloured clays as much as we should."

(12) "Art effects should supersede that cold whiteness which the Dutch and the English mistake for cleanliness."

(13) "Colour is capable of giving to objects a charm which they could not possibly have without it."

(14) "To the genius who has power to produce beautiful and vigorous ornament, and whose taste has, by years of study and cultivation, become refined and judicious, I can give no rules." (*Cassell's Tech. Educ.*)

Pictorial and Figure Designs in Tilework.—The successful employment of either the pictorial or the figure in decorative designs demands consummate skill as much in conception and arrangement as in execution.

For floor pavements, which should be unobtrusive, both appear unsuitable; and even in mural work they need to be used judiciously and under restraint, if at all. Commenting upon some of the work of one of the later artists employed upon the floor of Siena Cathedral, Mr. R. H. Hobart Cust, M.A., writes:—"But soon in his wild hunt for further effect he loses all sense of what is suitable for a floor, and, concocting a fine picture . . . . forgets entirely where it is to be placed. . . . It is difficult to express one's feelings on seeing what would be *eminently* suitable and even fine on a wall laid down to walk upon."

Decorative art needs constant attention to the motto, "For its place and in its place"; obtrusively placing the figure in incongruous situations is worse than omitting it.

But if there is one thing more than another the writer would like to insist upon in this paragraph, it is that nature should not be caricatured by those horrible representations called Romanesque, centauresque, caryatid, etc.—human head and shoulders on the body and legs of a beast, and so on, the result, surely, of an evil eye and an evil imagination.

There is a fitness of things, a propriety, a morality even in design, a line never to be overstepped without penalty, and this is where the writer for one would draw that line.

Then, again, the use of pictorial and figure subjects demands comprehensive historical knowledge, lest misleading ideas be conveyed; even eminent artists have at times appeared a little forgetful in this respect.

Once when Professor Petrie was in a humorous mood he penned the following sentences which well illustrate our meaning:—"Abraham in a full-bottomed wig, Sarah as a Dutch beldame . . . . David as a burgomaster—all these we have in the 'old masters'; very telling, very touching . . . . we laugh inevitably; to us they are incongruous; to the age that produced them they were inspiring realities. The seventeenth century outgrew all that. It was wiser. It knew of Roman sculptures; it had some idea of Greek art. . . .

So David became a Roman general, just as Roman as Louis XIV. or George II. . . . . Our century despised this false classical sentiment. Our fathers and grandfathers saw through all that. They knew that the Orientals must have dressed in oriental costume. They drew a Rebekah in the dress of a modern Bedawi girl, and Eleazar became a Bedawi sketch. The matter was so beautifully and simply settled . . . . and we have lately seen Greek pictures so learnedly painted; Andromache at the fountain, and all her neighbours, every one with a real Greek vase. . . . . Grand vases which never saw a fountain in their lives are here going once too often to the well.

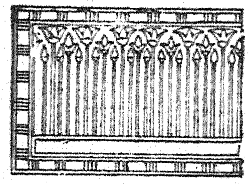


FIG. 299.

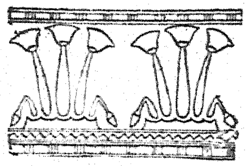


FIG. 300.

Decorative designs from Denderah. ("*Man. Egypt. Arch.*," p. 92, *Grevel & Co.*)

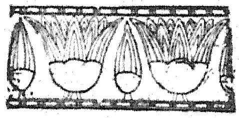


FIG. 301.

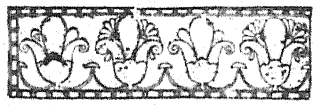


FIG. 302.

Decorative designs from Denderah. ("*Man. Egypt. Arch.*," p. 92, *Grevel & Co.*)

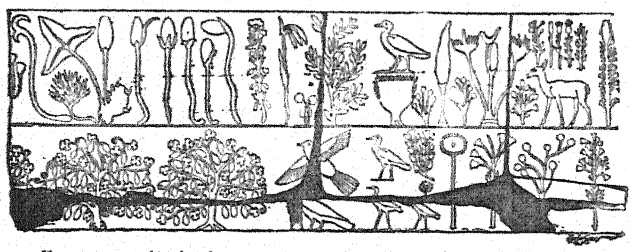


FIG. 303.—Dado decoration, hall of Thothmes III., Karnak. ("*Man. Egypt. Arch.*," p. 93, *Grevel & Co.*)

"Most persons will perhaps suppose that in the 'unchanging East' everything is made alike, from the time of Abraham downwards. Nothing is more deceptive than this shallow phrase; fashions change with successive races—with successive generations. In Egypt, where we can find the fullest material by which to judge, it is clear that fashion of manufactures changed quite as quickly as in mediæval Europe." (*Leisure Hour*, 1891, p. 229.)

Symbolism in Design.—Referring to decoration as practised by the ancient Egyptians, Professor G. Maspero avers that the sculptured figures, inscriptions, and hieroglyphs, which crowd the surfaces of the pylons and walls and columns, may be recognized at a glance as not having been placed at random.

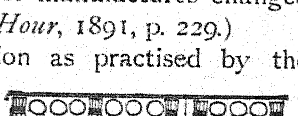


FIG. 304.—Frieze of uræi and cartouches. ("*Man. Egypt. Arch.*," p. 98, *Grevel & Co.*)

"They follow in sequence, are interlinked, and form, as it were, a great mystic book in which the official relations between gods and men . . . . are clearly set forth for

such as are skilled to read them. . . . . The floor of the temple naturally represented the earth . . . . the roof . . . . corresponded exactly with the Egyptian idea of the sky. Each of these parts was, therefore, decorated in consonance with its meaning. Those next to the ground were clothed with vegetation. The bases of the columns were surrounded by leaves, and the lower parts of the walls were adorned with long stems of lotus or papyrus, in the midst of which animals were occasionally depicted [fig. 299]. Bouquets of water-plants emerging from the water [fig. 300]. Elsewhere we find full-blown flowers interspersed with buds [fig. 301], or tied together with cords" [fig. 302]. (*Manual of Egypt. Archæology*, pp. 91–92, Grevel & Co.)

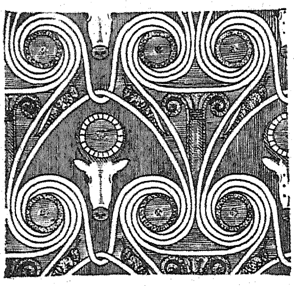


FIG. 305.—(*E.D.A.*, p. 34.)

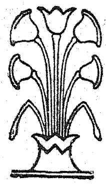


FIG. 308.—(*E.D.A.*, p. 66.)

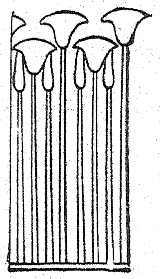


FIG. 309.—(*E.D.A.*, p. 67.)

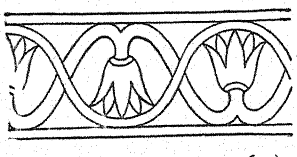


FIG. 306.—(*E.D.A.*, p. 64.)

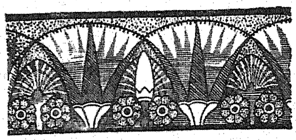


FIG. 307.—(*E.D.A.*, p. 65.)

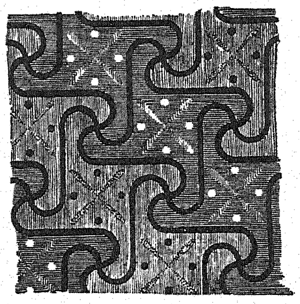


FIG. 310.—(*E.D.A.*, p. 37.)

Examples of Egyptian patterns and designs. (*From "Egyptian Decorative Art." By permission of Methuen & Co.*)

From peculiarities common to Egyptian ornament, namely, severity, rigidity of line, dignity, and symbolism, Dr. Dresser infers that they were a severe people, hard taskmasters, yet noble in their knowledge of arts, in their erection of vast buildings, and in the greatness of their power. In their frequent conventional use of the lotus flower in ornamentation, he recognizes the overawing influence of their priesthood, who, craftily and skilfully turning to account the anxious watchfulness of the people for the upspringing of this lotus, their harbinger of plenty, taught that in it abode a god, and that it must be worshipped. (*Cassell's Technical Educator*, vol. i. p. 51.)

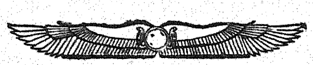


FIG. 311.—(*E.D.A.*, p. 110.)

In his *Egyptian Decorative Art*, Professor W. M. Flinders Petrie, F.R.S., etc., remarks that "The Egyptian treatment of everything great and small

was so strongly decorative that it is hard to exclude an overwhelming variety of considerations. . . . . The love of form and of drawing was perhaps a greater force with the Egyptians than with any other people. . . . . The question of the origination of patterns at one or more centres has been as disputed as the origination of man himself from one or more stocks. Probably some patterns may have been reinvented in different ages and countries; but as yet we have far less evidence of reinvention than we have of copying. . . . . Practically it is very difficult, or almost impossible, to point out decoration which is proved to have originated independently, and not to have been copied from the Egyptian stock. . . . . Some now claim most decoration as having some symbolic or religious meaning; of that I shall say nothing, as it is an hypothesis. But there is no question of the symbolical intention of many constantly repeated ornaments in Egyptian work, as the globe and wings, the scarab, or the various hieroglyphs with well-known meanings, which are interwoven into many designs." (*Egyptian Decorative Art*, pp. 2–10, Methuen.)

With regard to this winged globe, the Egyptian priesthood are said to have taught the people that this was the symbol of protection, and that no evil could enter where it was portrayed; hence this device was ordered to be placed on the lintel of every house.

Another notable example of symbolism in design is pointed out by Dr. Dresser, namely, the use of the equilateral triangle and of three interlaced circles in various adaptations, so frequently met with in Gothic ornament. This he considers as symbolic of the unity of the Trinity. In this manner he asserts that all good ornaments make utterance, and when beholding them he suggests that we should endeavour to give ear to their teachings. (*Cassell's Technical Educator*, vol. i. p. 90.)

Details.—Of the myriad details of patterns now in use, reference to the pattern-sheets of many leading makers only can impart a correct idea. To discuss this mass of minutiæ, or probe into details of design, is outside the scope of this brief notice. It is only possible to illustrate a very few of the newer designs, which appear to point out one of the ways taste or fashion may be trending.

By the kindness of the editor of *The Studio*, four illustrations, from pp. 271 and 272 of *The Studio*, vol. xxvi., of tile designs, exhibited in the National Competition of Schools of Art, 1902, are shown in figs. 312, 313, 314, 315.

Commenting upon these designs, *The Studio* remarks that "A tiled dado by Arthur Kidd (Sunderland) is one of the really admirable and distinctive group of designs for pottery to which we have already alluded. The border is perhaps the most successful part of the design, but the composition as a whole is good and the colouring very agreeable."

"Another and quite delightful tile-pattern is by Harry Allen (Burslem);

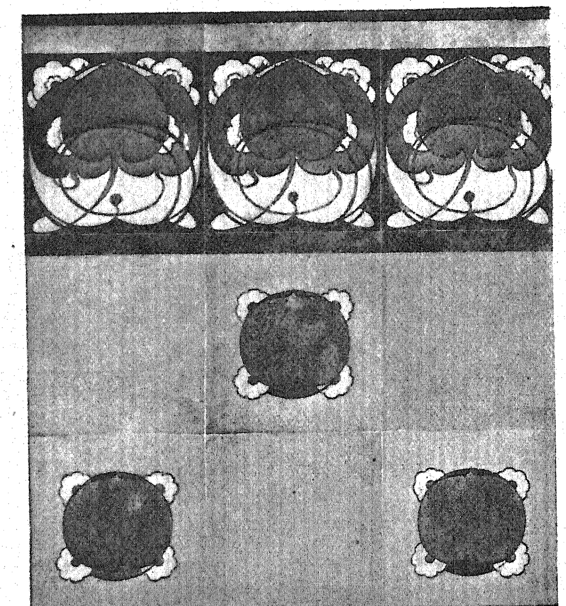


FIG. 312.—Design for tiles by Arthur Kidd (Sunderland).
(*By permission of the Editor of "The Studio."*)

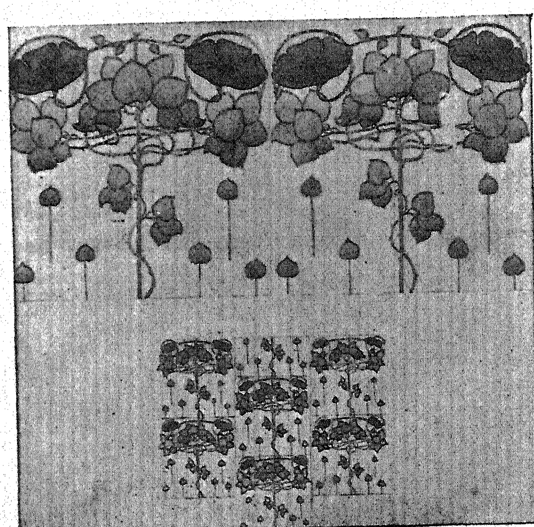


FIG. 313.—Design for tiles by Harry Allen (Burslem).
(*By permission of the Editor of "The Studio."*)

here the working drawings are especially good, and the charm of the decoration is not lost by its having come out in the finished model, after firing, in quite a different colour."

"The purpose of the design by Rowland Gill (Colchester) is more elaborately set out in a series of drawings which show the tiles in position as a vertical decoration of broad grate checks, as well as in their finer detail. The composition and colouring here are equally good, and the unpretentious beauty of the figure is admirably realised." (*Studio*, vol. xxvi. p. 276.)

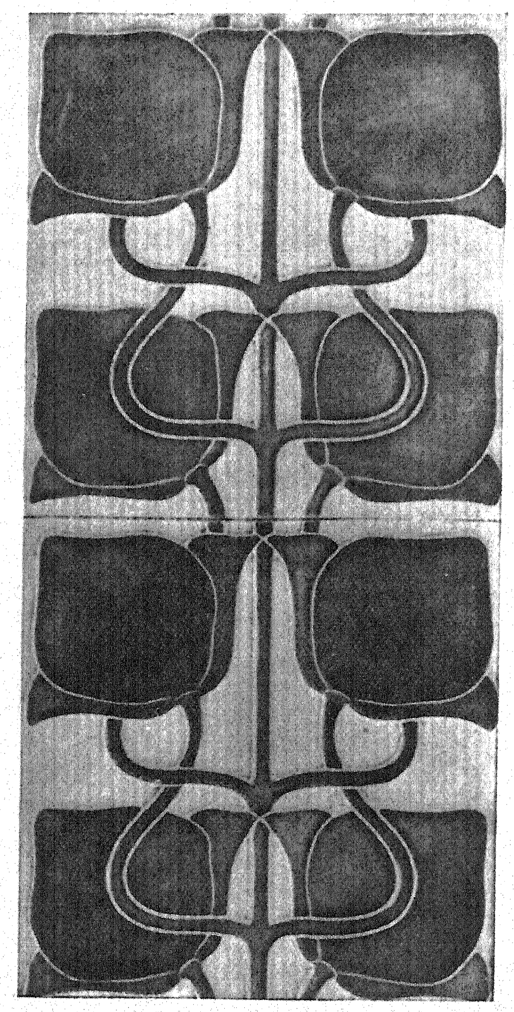


FIG. 314.—Glazed tiles. R. Gill (Colchester.) (*By permission of the Editor of "The Studio."*)

"Another very successful panel, for an overmantel, is by Nina Morrison (Liverpool). The design, treating of a family procession of mediæval figures, is graceful, spirited, and full of action." (*Studio*, vol. xxvi. p. 274.)

Out of a considerable number of designs for Christmas and New Year cards published as a supplement to *Photography* Christmas Number for 1901, two appear to lend themselves very well to use as brocaded-ground panels in wall-tiling, either above or within the dado. For this reason the proprietors of *Photography* were approached, and their consent obtained for reprinting these in this volume. (See figs. 316 and 317.)

Some years since the *Staffordshire Sentinel* published two very piquant articles upon "Ceramic Decoration" by a contributor under the *nom-de-plume* of "Stylus." Although these applied primarily to domestic wares, the opening sentences may not be uninteresting or inapplicable here. They read as follows:—"The remark of Oliver Wendell Holmes, that every man is three men—the man he himself thinks he is, the man his friends think him, and the

FIG. 315.—Cartoon for a panel in an overmantel. By Nina Morrison (Liverpool).

real man as God Almighty made him—may be quoted by analogy, aptly enough, with regard to the sending forth of new designs and their suitability to the public taste. For instance, every pattern and sample has to go through several ordeals, examinations, alterations, and emendations, or what you will. When a pattern leaves the designer's hand there is considered :—

1. What the designer thinks the public will like ;
2. What the manufacturer thinks the public will like ;
3. What the traveller thinks the public will like ;
4. What the dealer thinks the public will like ;
5. What the public really do like ;

which, as I shall show, is not at all the same thing. There needs no apology for writing at some length on this subject, for it is

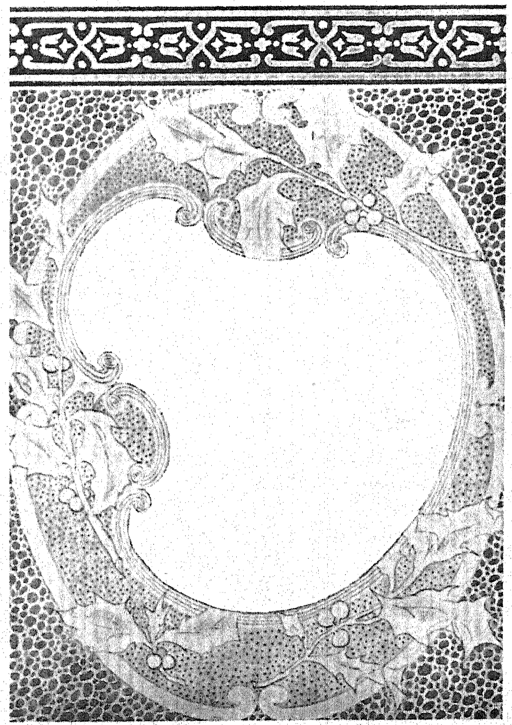


FIG. 316.—From *Photography* Christmas Number, 1901. (*By permission of Iliffe & Co., Coventry.*)

admitted on all hands that nowadays the whole secret of success in the potting trade is found in one issue, and that is suitable and tasteful decoration. The traveller who carries the most tastefully decorated samples (other things being equal) takes the best orders; and a new and striking pattern or shape will often command prices higher than the generally accepted scale of such goods as are equal in cost of production and all other respects, but

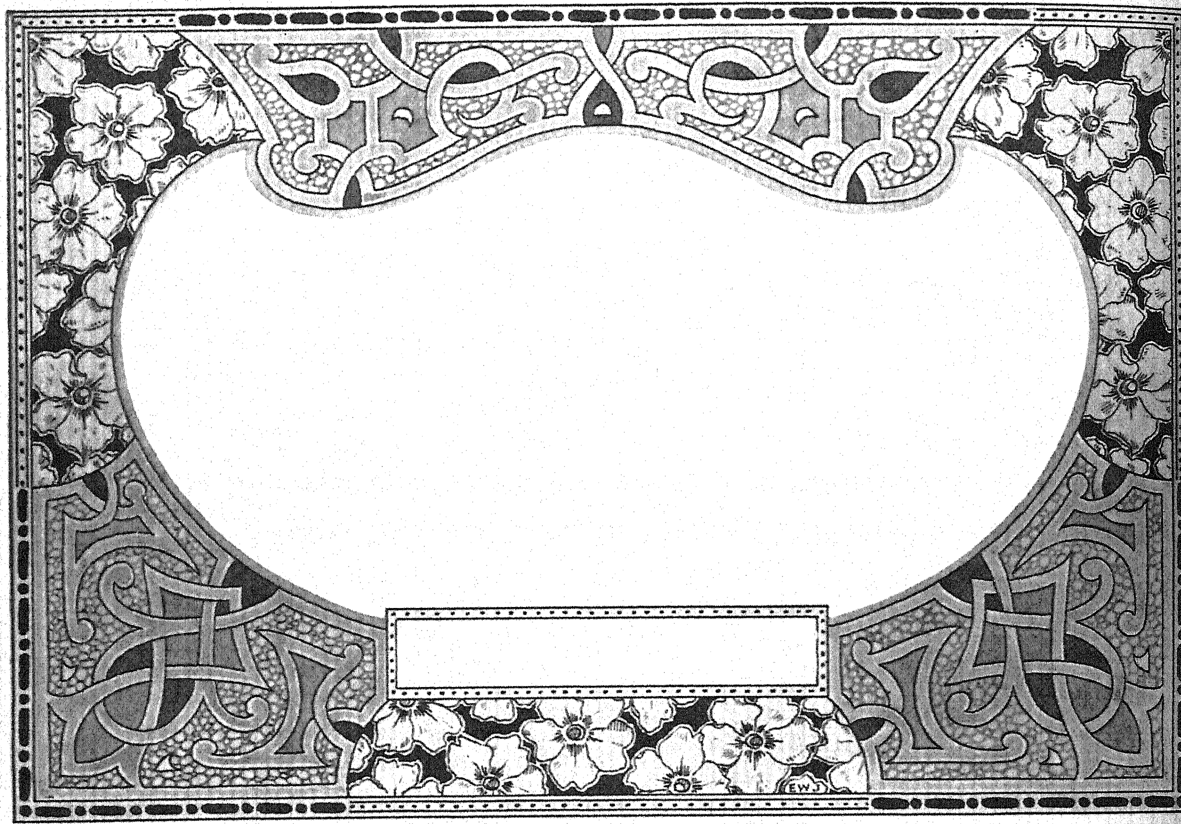


FIG. 317.—From *Photography* Christmas Number, 1901. (*By permission of Iliffe & Co., Coventry.*)

with a commonplace and ordinary print or pattern on them." (*Sentinel*, 11th April 1892.)

Then, again, R. L. Stevenson has written:—"About art, think last of what pays, first of what pleases. It is in that spirit only that art can be made." This looks very antagonistic to commercial principles, but is it really so? Read it again; its terseness and "bedrock" truthfulness should not hide from us its usefulness as a commercial axiom. Does not the commercial method of making things pay an excessive profit often lead to flooding

markets with inferior products hurried through the works at quickest speed, that disgust the best purchasers, and eventually often destroy the demand by destroying the fashion? Therefore, beware of over-anxiety for profit.

In conclusion, it may perhaps truthfully be said that, supreme above all rules, the gift of refined and intelligent originality is the one a designer covets most; with this, and with sufficient strength of purpose to overcome obstacles to its free exercise, the designer is honoured and happy. And when the cloak of the art-prophet has really fallen upon him, let him never be turned aside by the ridicule of mediocrities from the path in which his intelligence is leading him; let him never compromise with his muse simply to conform to the conventionalized notions of self-constituted critics; but ever follow the guiding genius nature has endowed him with.

Tilework Designing in Practice.—To secure to those who honour this volume by perusal the advantages of a long practical experience in tilework designing and application, such indeed as the writer himself is personally unable to offer, an arrangement was made with Mr. Ambrose Wood, of Hanley, a gentleman whose lifelong work has been principally in this direction, to write a special article upon the subject. This was completed in due course, and is as follows:—

"DESIGNING FOR ORNAMENTAL TILEWORK AND FAÏENCE.

"By AMBROSE WOOD, of Hanley, Staffordshire.

"The writer of this article bases his remarks on an experience of thirty-eight years, much of that time having been devoted to designing, and to the practical part of making plans and working-drawings. Every branch alluded to in the following pages has been constantly before him; and the various points being expressed in plain words, to the exclusion of unnecessarily abstruse technicalities, he trusts that a clear conception of the whole of the subjects treated may be conveyed to the reader.

"Art of an improving character has of recent years been brought to bear upon manufacturers generally, and upon tiles and faïence particularly, and wares of more truly artistic character produced. Our private houses and public buildings, too, for which many of these goods have been adapted, have increased considerably during the last ten years; and, as a result, to-day employment is found for thousands of British artisans in producing these high-class goods in tiles and faïence. Unfortunately, there is also a demand for inferior qualities, and there are makers manufacturing accordingly.

"But to come to the point of our subject. The nature of these units of tile designs having already been fully described in foregoing chapters, we may commence by prefacing this special article with a preliminary word about plans and drawings.

"Where working-plans are required for patterns made up of large-sized

tiles, the same should be drawn to a scale of ½-inch to a foot; but, generally speaking, the working-plan should be drawn to a scale of ¾-inch to a foot, especially when the design is of an elaborate character or made up of small-sized tiles. Lines must indicate where borders are intended to run, and the pattern should in every case be filled in at that part of the plan where it is desired the tile-fixer is to commence laying. The sizes of strips used for borders or margins should in every case be marked in figures, so as to prevent the possibility of mistake.

"FLOORING-TILES.—It must be borne in mind that under this head I am solely referring to the dust-made tiles; these are most commonly known to architects and the trade as 'tessellated' or 'encaustic' floor-tiling. Wherever it is so expressed, it is understood that such tiles are ½-inch in thickness.

"Many years ago the old pattern known as 'The Alhambra' (see Pl. XXXVI.) was most extensively used, as also patterns made up of the ordinary 'octagon and dot' (Pl. XXXVI.); but of recent years popular taste has gone in other directions, and designs of geometrical fulness are much more used, after the style of the design marked 'geometrical' (Pl. XXXVI.).

"Further, there is a special leaning in particular localities for tile designs of varied colourings; as, for instance, in North Wales light colours consisting of drab, salmon, chocolate, white, and sage, in fairly rich combinations, are often selected. This may be accounted for to some extent by the fact that the roads there are largely of limestone formation; hence the light-coloured dust and footmarks when wet do not so easily disfigure the pavement.

"Buff colour has in a marked degree been left out from all kinds of designs, even the most untrained person often objecting to its use, as, being a specially light tint, it so soon shows dirt and objectionable marks when even ordinarily used.

"Again, in London there is a distinct preference shown for black and white tiles; these being used most largely for outside forecourts, porches, and halls, also for scullery floors and underground conveniences. An enormous demand for this particular kind of tile exists, and the pattern marked 'vitreous' on Pl. XXXVI. shows the adaptation of the Grecian key-border to same, which, when properly fixed with good quality vitreous white tiles, make a really first-class and effective pavement.

"There is an increasing demand amongst architects and persons of æsthetic taste for a most simple introduction of red tiles, 6 inches by 2 inches, laid herring-bone fashion. These are used for vestibules and halls, also for conservatories, corridors, basements, outside bay-paths, and forecourts; indeed, there is a general agreement amongst men of taste that flooring of one colour, particularly red, is most suitable for effective flooring, and to harmonize with the general decorations often used.

"Owing to the development of electricity, many generating stations are being built; these afford a new scope for tiling.

"Floors formed of plain $4\frac{1}{4}$-inch red tiles, either fixed with a broken joint or laid diagonally, are a suitable kind. So also are 6-inch by 3-inch red, if sufficient care be taken to have only those tiles which are of a hard texture. Similar combinations are particularly suitable for engine-houses, etc.

"'Tessellated' tiles are *small* squares or pieces, and this term is most frequently used by tile-fixers; generally including tiles from a size $1\frac{1}{16}$ inch square and under. Of these sizes, effective designs are made for shop doorways, and a name is often formed by the same being worked in as a panel or centre-piece with borders around. These can be made in varied sizes to suit almost any space required.

"'Encaustic' tiles are of two kinds. Originally the term was applied to what are now known in the trade as 'slipped encaustics'; these were mostly a very expensive kind of tile, made in several colours on a 6-inch by 6-inch square, and almost invariably 1 inch in thickness. They formed a very handsome pavement, and some are to be seen in our oldest buildings. The design marked 'slipped' encaustic, Pl. XXXVI., will give an idea of the character of these tiles. They were hand-made, and included amongst their colourings jasper blue, green, sage, and white; they are, however, seldom used at the present time. By the introduction of machinery, other and cheaper forms of 'encaustics' are now made, $\frac{1}{2}$-inch thick, from dust-clay instead of plastic clay and slips. These are effective, and are used in smaller quantities, associated with plain tiles, for increasing effect in flooring designs.

"In preparing designs, it is most desirable to bear in mind the purpose for which the pattern is intended to be used. In narrow halls the border must not be too wide, otherwise it will appear to reduce the width of the floor-space. For long corridors, in public buildings and offices, it is wise to break up the lengths by putting in panels wherever a pilaster or arch lends itself to the purposes; and when there is a curve or sweep at a prominent angle, if the border is turned to the same radius, and the centre of pattern cut to same, the result is more effective. This, of course, entails much extra labour in cutting and fixing, but, if well done, it invariably gives greater satisfaction, besides being more truly artistic.

"In designs generally, it is desirable to avoid making any combination which appears 'spiky,' as anything of that kind makes one feel unpleasant when treading upon it. What is wanted is a pattern arrangement that supports the appearance of solidity, without any part standing out with undue prominence.

"When designing tilework for use in warm climates, as in India or Australia, remember that the spaces that need covering may often be large; in such cases, larger sizes of tiles may with advantage be introduced, with proportion-

ately wider borders and strips. For such countries a quiet arrangement of colour is necessary, in which drab (light and dark shades), salmon, buff, cream, and chocolate-coloured tiles should largely predominate.

"Respecting church tiling, ecclesiastical architecture undoubtedly demands specially designed flooring, and only comparatively few persons have been completely successful in this department of the art of the tiler. Colour, form, pattern, size should each blend appropriately and harmonize with the surroundings of a place of worship. The colourings should be subdued, and the general design unique and special to the building wherein the work is laid.

"That eminent church-architect, the late Mr. Welby Pugin, appeared to favour red tiles largely for the aisles and nave, with chocolate-coloured tiles introduced rather sparingly; whilst for the chancel he adopted richer and more elaborate designs, including indented or incised glaze tiles, and bands of dark green-glazed tiles.

"Many architects of note have at various times supplied their own designs for this class of tilework.

"For chancel tiling, encaustic tiles may often be introduced appropriately, and in most cases glazed tiles may be sparingly used with good taste. For aisles, the simple 6-inch by 3-inch or 6-inch by 2-inch red-colour tiles, of rather dark dull shade, and laid in herring-bone style, can be advantageously used.

"MOSAIC.—For better-class work, such as vestibules, large conservatories, hotel entrances, shop doorways, and the like, there is now a steady demand for ceramic mosaic. For intricate and effective designs, these small pieces lend themselves favourably to the designer, and in the hands of a skilful artist much may be done. Moreover, this class of tilework is specially suited to situations where hard wear is likely to occur; hence, for museums and public buildings of almost every description nothing better can be obtained.

"This material affords large scope in the formation of elaborate centrepieces, graceful and foliated borders, pleasing ornamental scrolls at angles, and can be used with almost equal advantage for flooring either small or large spaces.

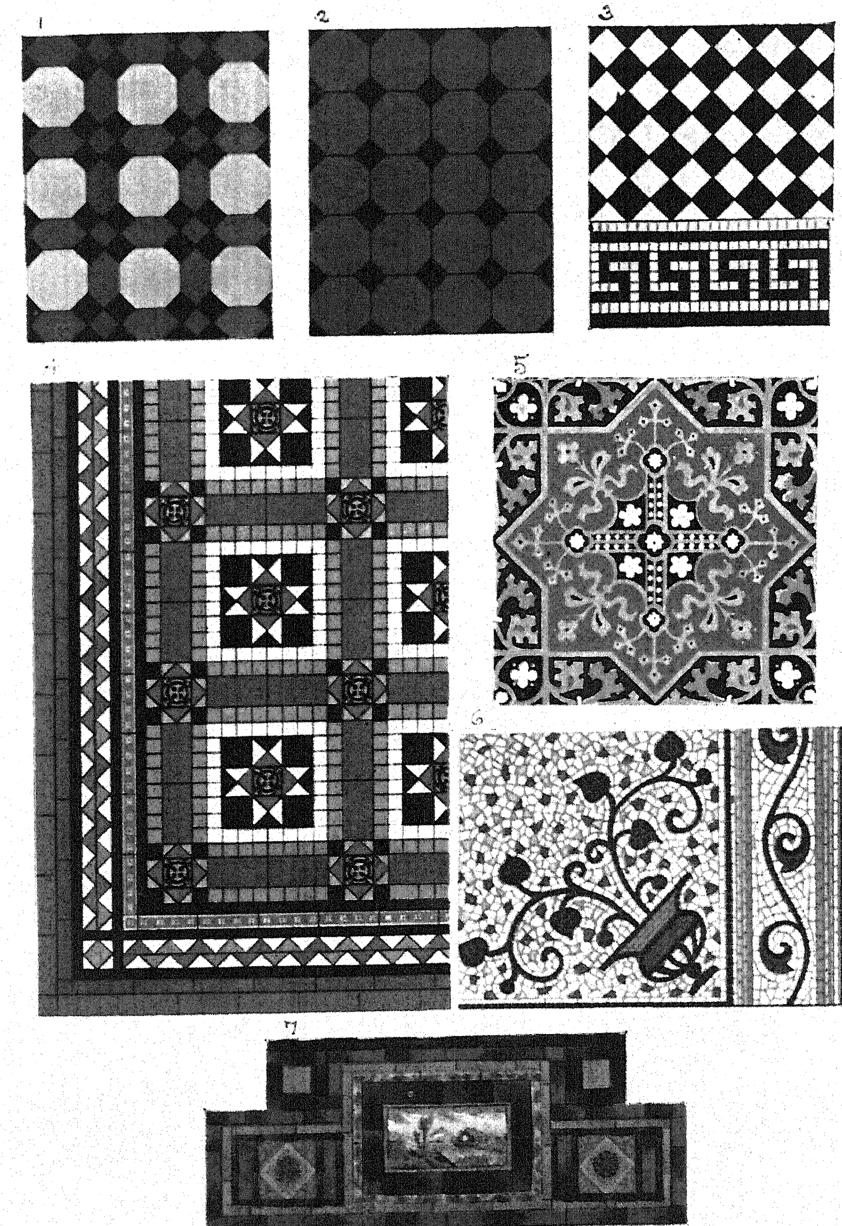
"The ground-work should be of a quiet self-colour usually, although in some few instances more lively shades, such as grounds of salmon colour, chocolate, sage, and even blue, may be used.

"Inscriptions in letters of a free-flowing type are often worked into the general design in ceramic mosaic flooring; and altogether one may, with good reason, hope to see the still further extension of the use of this excellent and enduring pavement.

"Two very small examples of ceramic mosaic tilework are shown in Pl. XXXVI., and others may be noted on Pl. XXXII.

"In preparing this sort of flooring, it is absolutely necessary, in the first place, to have correct dimensions of the space to be tiled; then the design

Pl. XXXVI.



is drawn out to full size upon strong paper, lettering on right and left hand figures, angles, etc., being reversed by the draughtsman.

"This full-sized drawing is afterwards cut up into convenient sections, so as to facilitate the putting of same together. The sections should not be too large, otherwise they would be inconvenient to handle in their manufacture, as well as troublesome for fixing.

"Upon the sections the varied ceramic mosaic tesseræ are placed face downward, and glued in position, according to the design. When each part of the design is filled in, and this has set, the sections are ready for use.

"A key-plan to any scale (usually about 1 inch to the foot) is made out, simply giving a number to each section for subsequent identification and correct arrangement by the fixers. Fig. 318 may be taken as an example of such a key-plan for ceramic mosaic work.

"Mosaic is also peculiarly fitted to serve as a permanent mural decoration in ecclesiastical buildings. A fine example of its application to this purpose,

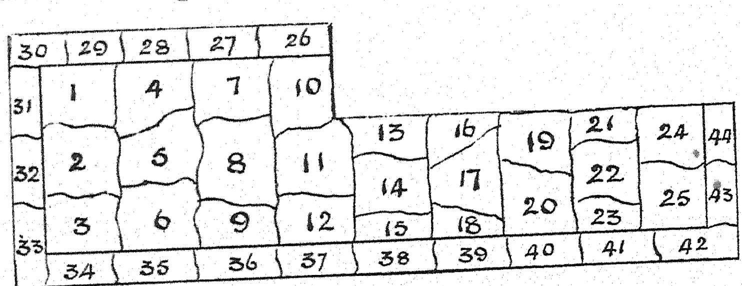


FIG. 318.—Key-plan for mosaic-work.

of recent date, may be seen in Armagh Roman Catholic Cathedral, where some superior ceramic mosaic work of this nature has been fixed in the Lady Chapel and in two side chapels and aisles, some parts extending to a height of 85 feet upon this surface. Saints and angels and incidents of a Biblical character are portrayed in mosaic, the figure-subjects being relieved with some gold-surfaced tesseræ.

"Mosaic may be worked with fragments of glazed tiles, particularly in the case of friezes, cornices, and the like. In this way tradesmen's and business signs may be artistically and effectively exhibited on the façades of banks, shops, restaurants, clubs, etc.

"HEARTHS.—Many pages might be written descriptive of the varieties of tilework in use for hearths, for during the last twenty years this particular branch has received considerable attention from designers, artists, and manufacturers. Hardly a mansion, or even an ordinary dwelling-house, is now built without being fitted with glazed-tile hearths of one kind or another. Changing taste, too, even in that relatively brief period, has played an

important part in creating a demand for different combinations and adaptations. Something new is ever being called for, hence continual change is going on in this direction.

"Formerly the old hand-made glazed 6-inch by 6-inch encaustic tiles, 1 inch thick, were almost the only ones used. The several colours forming the ornament being slipped on the surface, by a somewhat tedious process, these tiles were expensive as they were durable, the average price being about thirty shillings per square yard. Now, however, they are quite the exception for this purpose, although it is more than likely a return to some modified form of this class of tile may be anticipated.

"Meanwhile, effective designs can be made up of richly enamelled tiles, in tints of crimson, greens, greys, yellows, and a great variety of browns. As far as possible, the shade chosen should correspond or harmonize with the general decoration of the room in other respects. The most widely preferred sizes for the individual tiles composing hearths are probably $4\frac{1}{4}$ inches by $2\frac{1}{8}$ inches, 6 inches by 2 inches, 3 inches by 3 inches, or 6 inches by 6 inches, with sometimes a strip round to form a border. According to the taste of architect or occupier, the tiles may be laid in line or with broken joint. For convenience of laying or removing, these hearth designs are sometimes arranged so as to be easily grouped into a single piece, by the tiles being cemented together on slabs of slate; an example on very minute scale is shown in Pl. XXXVI.

"The ordinary size of a hearth is 4 feet by 1 foot in front of the mantel, with extra tiles to go under fireplace. For several years there has been a large and unusual demand for crimson enamelled tiles, especially the 6-inch by 6-inch briquette pattern; these have proved particularly suitable for dining-room and hall hearths. When more elaborate designs are required, something of the character shown on Pl. XXXVI. may be devised, the panel being either pictorial or conventional, according to fancy.

"FIREPLACES.—For this purpose many effective designs can be made in enamelled tiles, as surrounds to either fire-grates or gas-stoves. The writer has recently supplied a large quantity to several first-class residences in Hampstead, London, N.W. These surrounds were largely composed of tiles measuring separately $4\frac{1}{4}$ inches by $2\frac{1}{8}$ inches, 3 inches by 3 inches, and 6 inches by 6 inches; and hearths were made to correspond. The colours used were chiefly crimson, old gold, golden-yellow, cream, light green, shrimp-pink, and a rich deep tint of blue. The surrounds were finished round with marble slips and hardwood overmantels. When completed and fixed in this manner, the richness of effect was all that could be desired.

"Side panels for grates are sometimes constructed in tiles 6 inches by 2 inches, $4\frac{1}{4}$ inches by $2\frac{1}{8}$ inches, or 3 inches by 3 inches; and these may be slabbed in various sizes, according to the nature of the design.

"Curved or structurally moulded fireplaces, as shown in fig. 319, may be designed by arrangements of 3-inch by 1-inch, $4\frac{1}{4}$-inch by $2\frac{1}{8}$-inch, or 6-inch by $\frac{1}{2}$-inch tiles.

"Glazed fireclay briquette fireplaces may also be designed, by building up from different units of bevelled, plain, or antique shaped briquettes, of sizes such as 6 inches by 2 inches by $2\frac{1}{4}$ inches, or 9 inches by $4\frac{1}{2}$ inches by 3 inches.

"One such arrangement is shown in fig. 320, and, although plain and quaint, it at least may be suitable for certain situations, and, above all, *may* be in fashion.

"Similar designs may be made up in larger pieces, five large portions making up the whole front, if desirable.

"Another style of fireplace, known as the 'faïence' fireplace, may also be the field of operations for a designer. At present these mantelpieces are made in a large variety of designs, and glazed or enamelled in equally profuse variety. Out of a large number of examples I have selected one (fig. 321) as an illustration of a simple, yet effective, design, which speaks for itself.

"It is made up of eighteen separate pieces, namely, six jamb-pieces, two caps, two spandrils, one arch-centre ornamental piece, centre-key, and

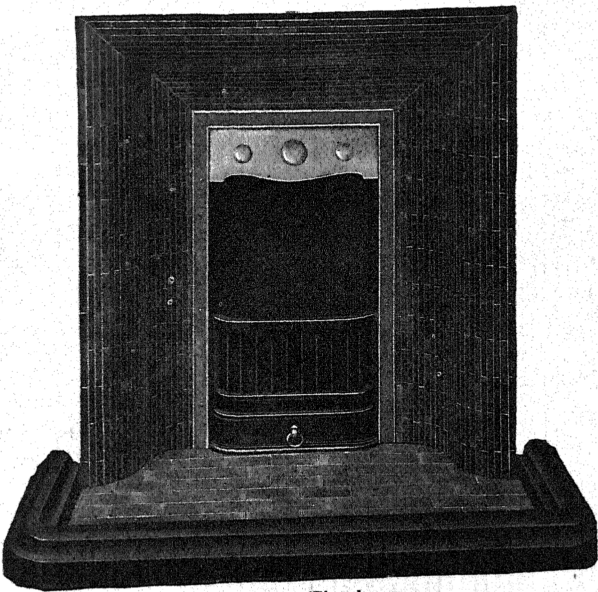


FIG. 319.—Fireplace.

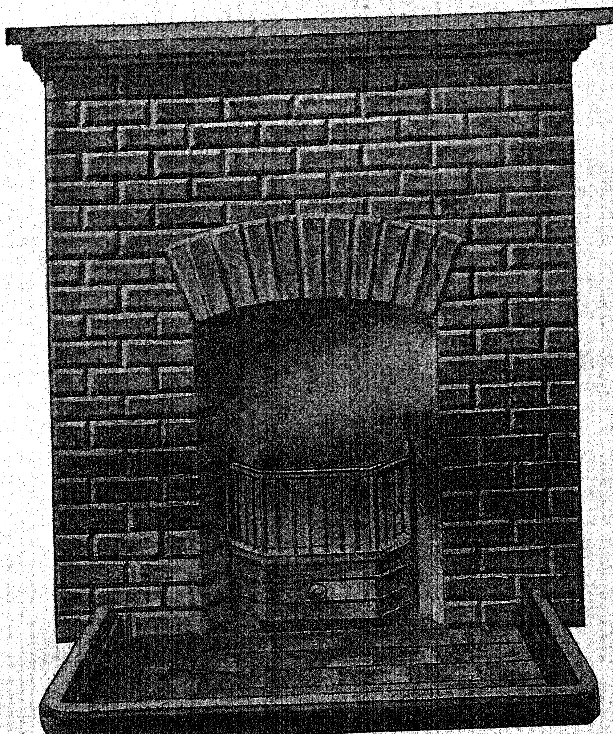


FIG. 320.—Briquette fireplace.

six shelf-pieces, all of which are easily fixed together by an ordinary workman.

"Similarly, glazed fireclay wares or 'faïences' may be introduced in fire-places in the form of artistic relief panels, size 38 inches by 12 inches, which

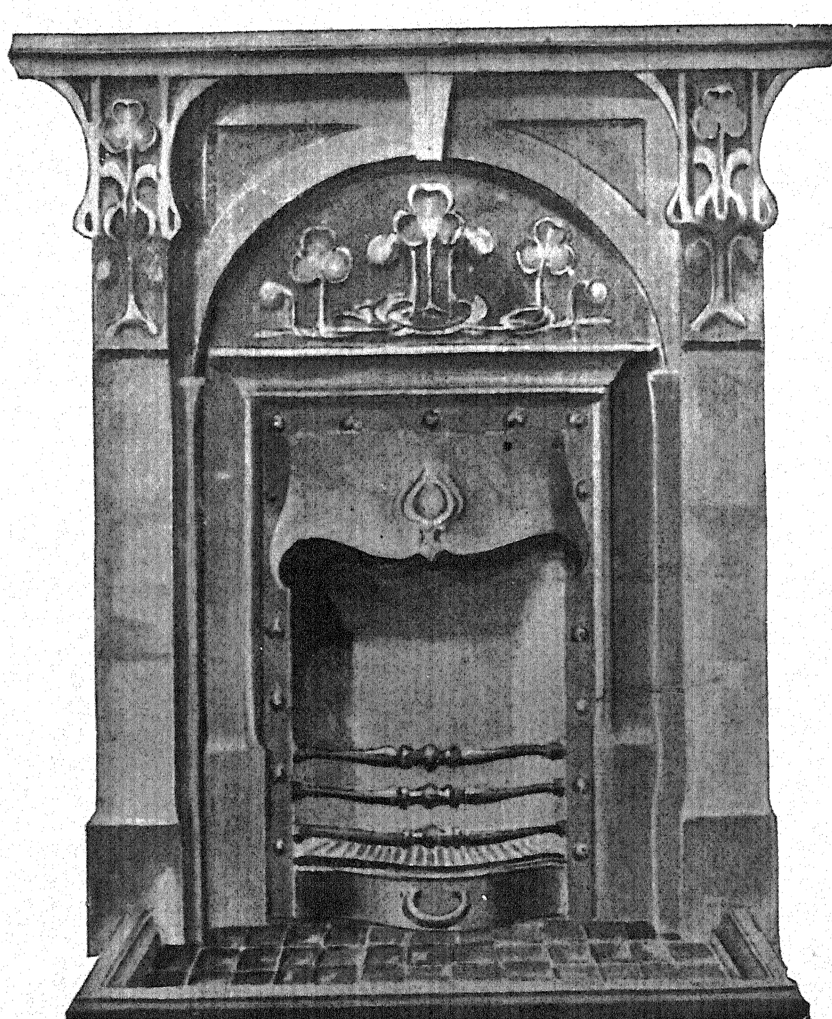


FIG. 321.—Faience fireplace.

are built up in constructing the mantel. Faïence surrounds may also with good taste be introduced (fig. 322).

"In working out details and colour-schemes for such ceramic wares, designers should bear in mind that, on account of the clay-body of this

fireclay faïence being usually of much darker colour than the bodies of fine earthenware wall-tiles, whatever colour of glaze or enamel is applied shows as a somewhat darker shade than it would on white tile-bodies; hence very bright shades of colour should not be shown on designs, because they may be very difficult of attainment by the manufacturer; and possibly out of harmony with the whole style of relief-work such as this.

"Faïence of this class is also used in the construction of stoves, such as are now largely used in hospitals, workhouses, banks, or large rooms for many purposes. These commend themselves owing to their cleanliness, power of storing heat, and their gradual radiation and diffusion of heat.

"The example shown (fig. 324) is one of Messrs. Woolliscroft's double down-draught stoves. Although this illustrates a very simple surface, the designer will immediately perceive decorative possibilities. The structure being of only moderate size, may therefore be elaborately treated without very great cost; and as it must necessarily take up a somewhat prominent and unique position in the room, within full view at the ordinary angles of sight, these stoves are peculiarly susceptible to artistic treatment.

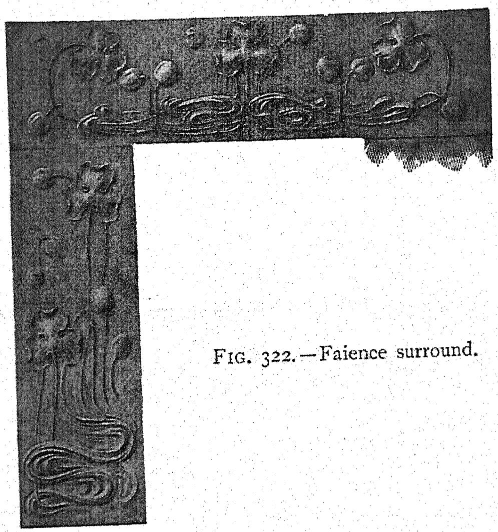


FIG. 322.—Faience surround.

"When it is desired that stoves of a more ornamental character shall be designed, the most elaborate application of decorated 'faïence' may be utilized, cutting up the corners of each stove with modelled shields in pilasters to which monograms, etc., may be added, the other parts corresponding with the style of ornamentation that may be adopted.

"When plain surfaces are preferred, these may be effectively treated by an adaptation to parts of 'chromo glaze,' the richness of colour produced, combined with the scope of design, being specially advantageous, and in every way suitable for such a purpose. For special decorations, 'sgraffetto' ornamentation might also be applied to these stoves, the shape and general form being varied in innumerable ways.

"WALL-TILING.—The multifarious applications of enamelled or glazed tile-work for mural adornment or sanitary protection create an equal diversity in designs.

"This affects not the surfaces only, which may be plain, embossed,

roughed, enamelled, encaustic, printed, lustred, or what not, but the form of the tile and the nature of its composition.

"The designer necessarily may have to consider means for attachment; the numerous patents for special indentations and undercuttings of the back are evidence of this.

"Again, his ingenuity must devise specialities for hospital constructions, so

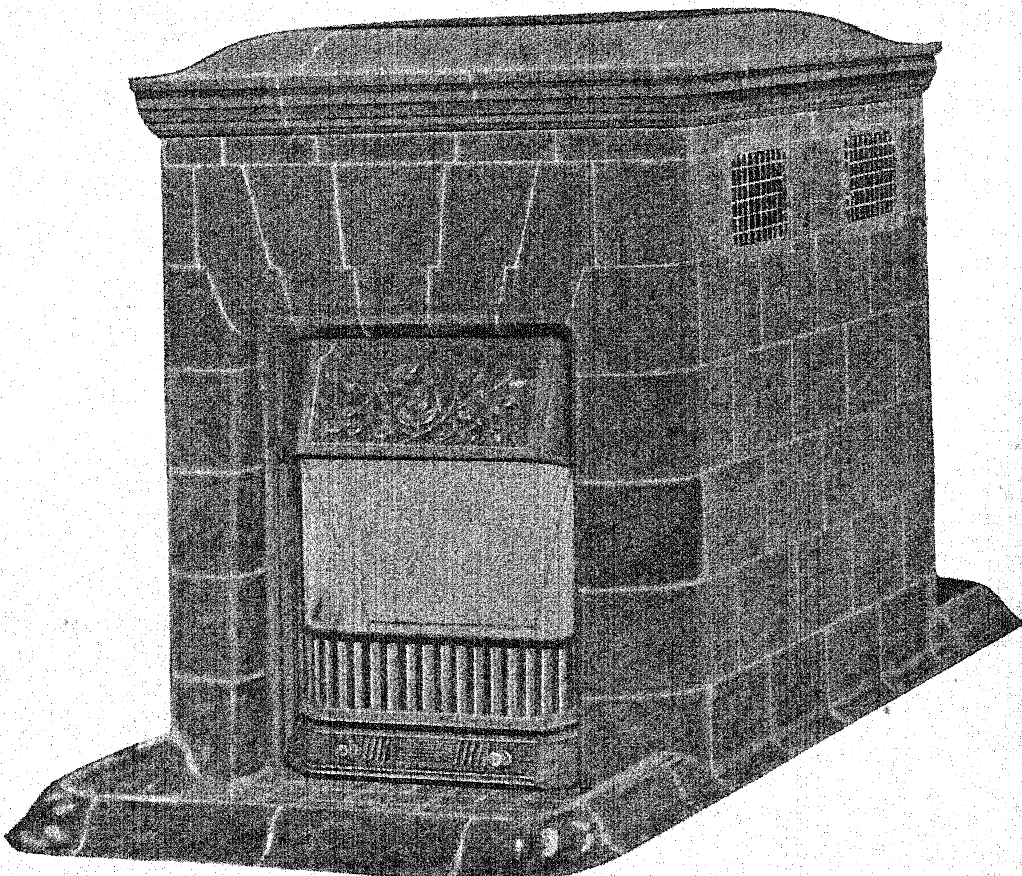


FIG. 324.—Faience stove.

as to eliminate corners in which germs of disease may accumulate, and so as to facilitate thorough cleansing.

"Into the vast detail of all the multitudinous possible surface treatments it is scarcely practicable to enter in the very limited space available now; therefore a few brief notes must suffice.

"As to embossment designs. These are largely made up of 6-inch by

6-inch tiles, the embossed surface of same not being too heavy, and mostly consisting of one-colour enamel.

"The characters of designs necessary for wall-tiles are various; mostly they should not be in too great a relief; on the other hand, the intaglio should not be too deep. Continuous designs are required in some cases, highly decorated or quiet in colouring, largely according to the idea and taste of the person who intends using them. For friezes the embossment may be much heavier and more pronounced, special running-pattern designs being mostly in preference.

"In embossment designs, 'set patterns' are requisite, whilst arrangements made up of lines on the tile rather than too much ornamentation are in accordance with good taste; these special line patterns going under the name of *cloisonné* or 'glazoline' style.

"As to designing of 'majolica' or 'enamelled' *wall*-tiles, and arrangements of same on application to the walls, this subject has been previously mentioned; but, in addition, I may add that the designer has a large scope here for useful introduction of hand-decorated tiles, forming coverings for walls in 'clalyn-glose' panels with 'barbotine' and fresco decoration. Plain enamelled, with cream and white glazed, ivory and glazing buff, all form material from which designs can be made up to suit whatever purpose they are required for. Machine-printed 6-inch by 6-inch and 12-inch by 6-inch are finely decorated tiles, and these with ordinary printed and transfers will help the artist to put together combinations to suit almost any taste.

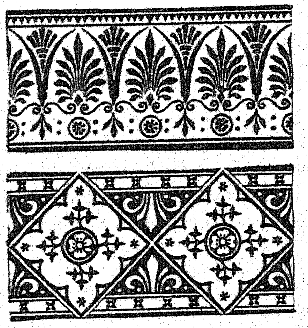


FIG. 325.—Printed-tile patterns.

"PRINTED TILES.—Patterns printed on 6-inch by 6-inch tiles, and afterwards glazed, are very numerous; and the scope of the designer is practically unlimited in this direction. The choice of style of pattern, continuous or broken, imitative or conventional, fine and neat, or bold and vigorous, need not be restricted, because they cater for very diverse demands, and all may be serviceable in their own appropriate spheres.

"A few examples of 6-inch by 6-inch set patterns, which may be printed in monochrome or polychrome colours, and a few border designs, are all that space allows us here. The decorative artist, when designing for the practical application of these elements, will, on the other hand, necessarily restrict his choice, according to circumstances. Thus, for dark rooms, combinations of light-coloured designs are desirable, whilst for well-lighted spaces darker-coloured patterns may be introduced.

"Again, the colours and patterns, particularly the former, must be considered

when decorating shop interiors, with a view to avoid colours likely to clash with the colour of the goods offered for sale.

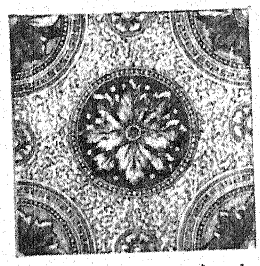


FIG. 326.—Printed and coloured tiles.

"Years ago printed tiles were extensively used for hearths and grates, but these have now in some measure been largely superseded by enamelled tiles.

"The use of wall-tiles for dados in the porches of ordinary dwelling-houses is also extending, and perhaps demands a word here, because they form such permanent decoration which may 'make or mar' the first glimpse of home, and thus should be worthy of consideration at the hands of the designer. Up to the height of about 4 feet elaborate compositions are often suitable (see fig. 327); and panels may be employed effectively associated with suitable dark-coloured, moulded, skirting tilework, and surmounted with a neat capping 2 inches or 3 inches deep.

"Then, above this, when the tilework is so continued, as it sometimes is, up to ceiling height, the design for the over-dado should be in more subdued colour, and of less elaboration, than the lower part.

"In the case of shops, the designer must necessarily take into consideration the nature of the trade conducted, the 'costs' limit imposed, the situation as to lighting and surroundings, etc. Where the money expenditure must be restricted, either plain cream and white 6-inch by 6-inch, or the same with a few printed tiles, may be all that is possible. When this is not the case, panels, cornices, friezes, and all manner of elaborations are admissible, due regard being paid to the particular trade. Counters, too, may also be formed of tiles in keeping with other portions of the interior decoration.

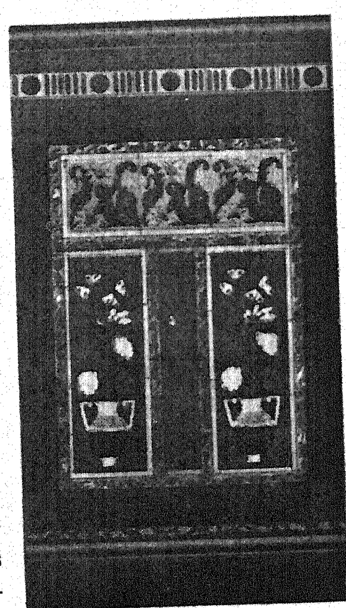


FIG. 327.—Panel dado for porch.

"In the case of restaurants, where long spaces may have to be designed for, to secure effective results it is advisable to introduce ornamental pillars of slight projection, and devote certain portions of the upper part of intervening spaces to panels of hand-painted work, representing appropriate subjects. In some cases, mirror panels are specified; when this is so, it will be found advisable to design a composition of the surrounding tilework in darker tints

of colour than would be used when the whole area is covered with tiles. The same applies to the treatment of confectioners' shops.

"PUBLIC BATHS.—Designs for this class of building should present a tolerably bright, cheerful appearance. Much of the work may have to consist of merely plain-glazed tiles; but, on the other hand, the vestibules and corridors offer a field for designing of more elaborate pretensions; enamelled and embossed tiles may in such portions be freely introduced, preference being given to the larger-sized tiles and to light tints of coloured glazes, to secure the boldness of design suitable for large spaces.

"Whenever possible, glazed tiles should be used in preference to glazed bricks, tiles making an altogether neater finish. This applies also to the lining of the baths themselves.

"SCHOOLS.—Here, again, designs should be made of a bold effective type, the dados to corridors and entrances being altogether of a different style from those used for ordinary rooms. In some portions, tiles illustrative of educational subjects may with advantage be introduced.

"Generally speaking, the colours selected should be such as convey impressions of warmth and comfort, and the designs should be of restful *motif*; anything glaring must be avoided, so that the minds of scholars may not be diverted from their work.

"HOTELS.—Whatever uses are made of either tiles or faïence in large and well-furnished hotels, which are commonly expected to be replete with extraordinarily luxurious appointments, one main idea should be uppermost perhaps in the designer's mind when prescribing what shall and what shall not be introduced.

"First of all, the style of architecture and intention of the hotel must not for a moment be forgotten.

"Then, with the foregoing, all requirements must be modified and blended into a homely and comforting effect.

"The work must be carried out in good style, and have a solidity, permanency, cleanliness, beauty, and even gorgeousness in certain portions.

"NATIONAL AND MUNICIPAL BUILDINGS.—Designing for the interior and exterior enrichment of very large erections by the use of ceramic wares necessarily falls within the province of the architect; and that, too, mostly of only those architects who have had large experience or special studies, to whom it would be presumption on our part to offer instruction.

"Nevertheless, whoever successfully adorns these immense structures with tilework or faïence must ever be considered a designer *par excellence*.

"The opinions of experienced men on these points having been recorded elsewhere in this volume, it is not necessary to dwell upon the subject here.

(Signed) "AMBROSE WOOD.

"SNOW HILL HOUSE, HANLEY,
"*February* 1904."

Drawing.—The duties to be performed in the drawing-office of a decorative-tile works comprise a very considerable yet absolutely essential part of the unproductive expenses of the business. In this department the majority of the quotations, estimates, designs, etc., for the approval of architects and clients are dealt with.

On the receipt of orders for tilework for floors, walls, etc., in almost every instance drawings have to be executed, showing the pattern and repeats, before the quantities of tiles to be manufactured or dealt with can be ascertained. Therefore, with a desire to render this publication as practically useful as possible, a few notes on this department are included. For these the writer respectfully acknowledges his indebtedness to Mr. R. A. Binnall, of Tunstall, and to Mr. Harold Moorcroft, of Wolstanton.

In the first place, the drawing department should possess a complete set of good mathematical instruments; it is misdirected economy to procure any other than the best of materials for drawing purposes, for a firm can show no worse advertisement than badly executed drawings, especially such as may be almost entirely produced by mechanical contrivances.

The most indispensable requisites are perhaps the following:—Parallel ruler or rollers, steel scale containing $\frac{1}{4}$-inch, $\frac{1}{2}$-inch, $\frac{3}{4}$-inch, 1-inch, and $1\frac{1}{2}$-inch scales, pair of compasses with steel legs, pair of compasses for pen or pencil, set-square 90°, T-squares, HH and HHH lead-pencils, ruling-pen for Indian ink, Indian ink, Chinese white, colours in cakes or tubes, and small sable-hair pencils—all duplicated or multiplied according to the volume of work. And to these, of course, must be added supplies of papers, cardboard, tracing-cloth, boards, drawing-tables, and sundries.

On examination of a floor-tile design, it will be seen that the diversity of colour and size of its component parts is very considerable, and it is at works where the floor-tile department is a large one that the greatest demands are made upon the drawing-office.

In the case of geometrical or tessellated floors, a ruling principle has its foundation in the properties of diagonal as compared with side measurements of squares. Sizes such as 5-inch, 4-inch, and 2-inch tiles, simple though they appear, do not lend themselves to geometrical arrangement with anything like the readiness or adaptability that sizes according with diagonal measurements do, such as $4\frac{1}{4}$-inch, 3-inch, $2\frac{1}{8}$-inch, $1\frac{1}{2}$-inch, $1\frac{1}{16}$-inch. For example, taking a 6-inch by 6-inch tile as a base square, if a $4\frac{1}{4}$-inch by $4\frac{1}{4}$-inch tile is placed upon it diagonally, the diagonal is found to be equivalent to the 6-inch tile crosswise. If upon these are laid successively, and always diagonally, 3-inch by 3-inch, $2\frac{1}{8}$-inch by $2\frac{1}{8}$-inch, $1\frac{1}{2}$-inch by $1\frac{1}{2}$-inch (see fig. 328), the same relations are exhibited, and this greatly facilitates the making up of varied geometrical patterns with the least variety of shapes. And with an occasional use of encaustic-figured tiles for centres or borders,

a pleasing diversity is attained. For that reason, these sizes have been generally adopted, and excepting mosaics, and the rather recent introduction of the disc or dot, they form the elements from which ornamental tessellated floor pavements are almost invariably composed.

Procedure in case of tessellated floors may be as follows:—Draw in pencil the outline of the plan of the floor, say to a 1-inch scale, *i.e.*, 1 inch to the foot, or one-twelfth. Then, taking as an example fig. A, Pl. XXXVII., note first that what is called the "figure" of the pattern is so much of it that, if similar parts were laid out consecutively and contiguously, they would complete the floor, except the bordering: or, in other words, a figure contains all the pattern.

For example, the space enclosed inside an imaginary line connecting the centres of the four black squares is a figure; or, similarly, the space enclosed by an imaginary line connecting the centres of the four encaustic-inlaid tiles.

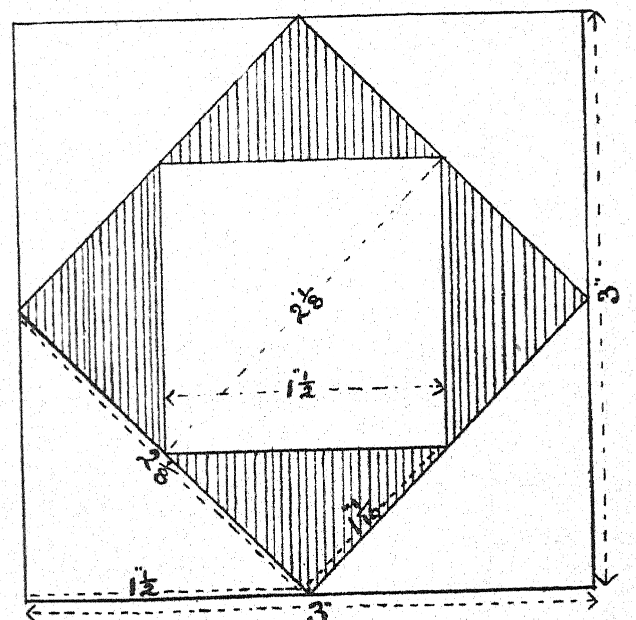


FIG. 328.—(*By permission of Messrs. Carter & Co., Poole.*)

The size of the "figure" of a floor design must always be measured either in a straight line parallel to the sides or at right angles to them. And as in the example the pattern is of diagonal or diamond form, the size of the figure may be ascertained by adding together the diagonal measurements of the separate tiles or parts thereof composing the figure. Thus, the centre encaustic-inlaid tile being $4\frac{1}{4}$ by $4\frac{1}{4}$, its diagonal measure is 6 inches; the two drab halves together make 6 inches, and the black being $2\frac{1}{8}$ by $2\frac{1}{8}$ its diagonal is 3 inches, so that the diagonal size of this pattern is 15 inches, *i.e.*, from centre to centre of the black squares. Now the border without the black margin has a 3-inch red tile, *i.e.*, $4\frac{1}{4}$-inch diagonal measure, and two 6-inch by $1\frac{1}{2}$-inch encaustic-inlaid strips, so the border is $7\frac{1}{4}$ inches wide, which equals $14\frac{1}{2}$ inches for both sides.

Supposing the hall or passage for which the floor is required is 4 feet wide, this would leave 2 feet $9\frac{1}{2}$ inches for the centre, allowing space for two figures

of the pattern, *i.e.*, 2 feet 6 inches, and leaving 3½ inches for the black margin, to be divided as equally as possible on each outer edge. In this case draw a pencil line down the centre of the outlined floor plan, mark off the border, calculating it in the manner just indicated; then upon the centre line mark off by scale 6 inches, then 3 inches, 12 inches, 3 inches, 12 inches, 3 inches, and so on. Rule the first diagonal line by aid of the set-square, then proceed all up the plan with the parallel rule.

If the pattern to be drawn is fig. B, Pl. XXXVII., the encaustic-inlaid tiles being 3 inches by 3 inches, the diagonal measure is 4¼ inches, making 8½ inches to each figure of which there are two kinds, and would be set off and plotted in 8½-inch distances by setting the compasses at 8½ inches on the scale and legging it along the plan, trying by accommodating the width of the border to bring in similar figures on each side. After covering the plan with 8½-inch squares, drawn on the square, commence measuring 2⅛ inches, then 4¼ inches, according to scale, to the finish, and rule by aid of the parallels all the diagonal lines.

Another way of drawing such a floor pattern would be to treat the whole pattern as a diagonal one, taking the portion included between the centres of the four "buff on red" encaustic-inlaid tiles as a figure which measures diagonally 17¼ inches—the tiles being 3 inches by 3 inches.

Procedure in the case of mosaic pavements.—Outline the shape of the floor to scale by the given dimensions. Then if it is to be a mosaic of geometrical pattern, the figures can be set out in a similar way to the tessellated floors just described, and details of the separate tesseræ filled in afterwards.

If it is a conventional treatment of some floral or other subject, the contours of the repeating portions can be drawn in outline first, and details filled in afterwards. If it is a pictorial design, then the ordinary rules of art-drawing must be followed, taking advantage of all the aids to accuracy afforded by ruling and measuring (see chapter on Mosaic).

The plan having been completed, it must be marked off in manageable sections and numbered. Then a full-size reversed drawing of each numbered section must be prepared on strong paper, drawn, coloured, and numbered to correspond with the scale plan. (See p. 805.)

In the case of wall-tiles, if either plain-glazed tiles, or 6-inch hexagonal or 6-inch octagonal, with dot tiles, are used throughout, practically no drawing is required. But if a wall is to be wholly or partially covered with tiles laid in a pattern, then the drawing will be done very much in the same way as with flooring tilework already described.

If a frieze, or surbase border, and skirting, or a dado, be introduced, then it is well to make a sufficiently accurate outline drawing as seen in elevation, both as a guide for computing the correct quantity of each kind of tiles forming the border, etc., and also for the guidance of the fixer.

Plate XXXVII.

Fig. A.

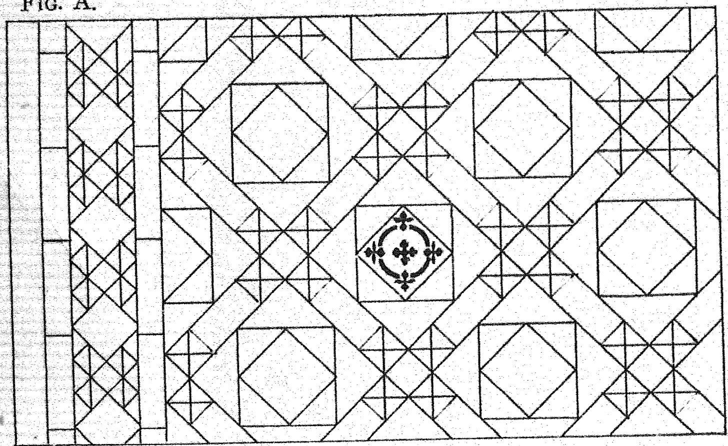


Fig. A.

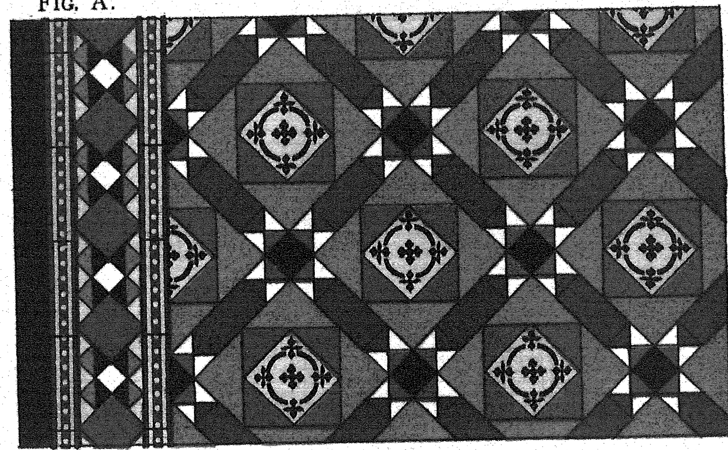


Fig. B

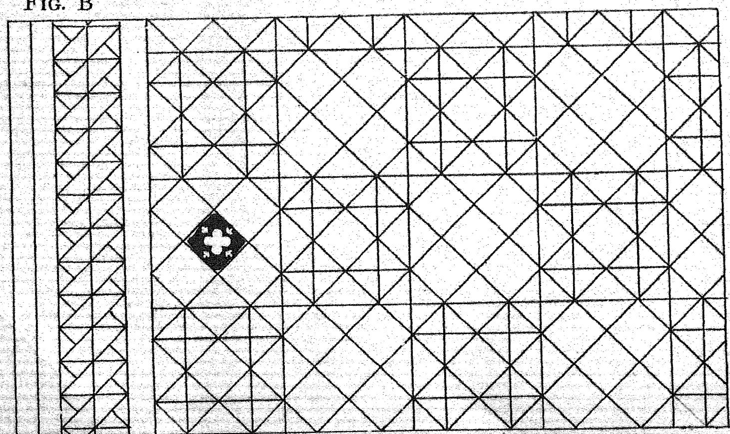
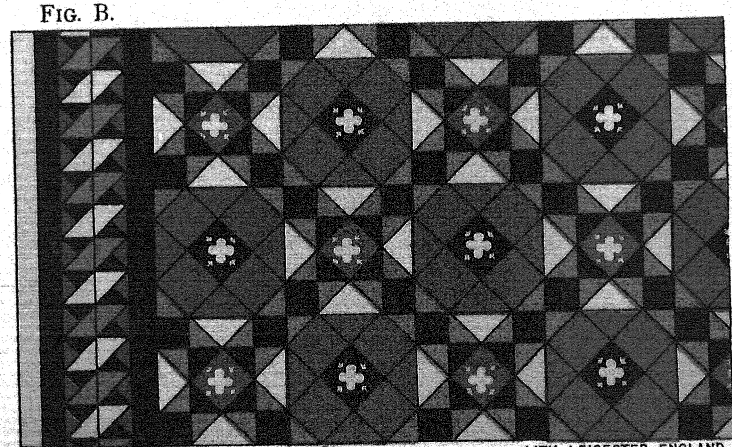


Fig. B.



J. FLEMING & Co.

LITH. LEICESTER, ENGLAND.

SCALE—ONE INCH TO A FOOT.

Skirtings formed of 6-inch by 6-inch tiles may be calculated lineally, and their total deducted from the total quantity of, say, 6-inch by 6-inch tiles

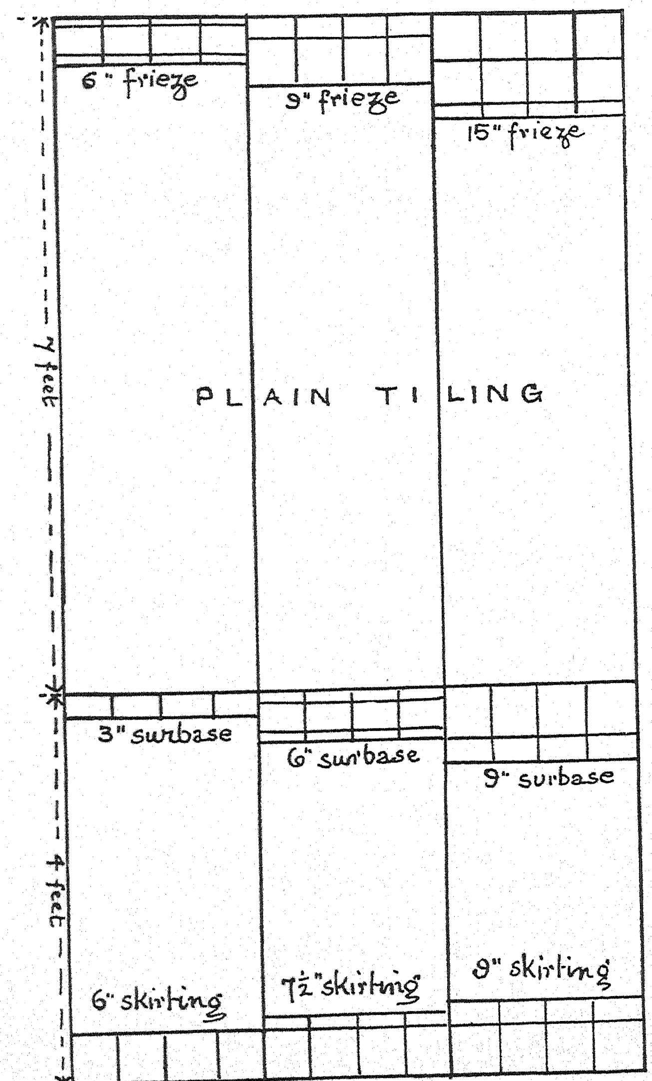


FIG. 329.

required for the whole walls, presuming the walls are to be covered with 6-inch by 6-inch hexagon, octagon, and dot, or some simple sizes of tiles.

Estimating.—The writer makes no pretence of having personal experience in the matter of estimates for tilework, but in all that follows is simply repeating directions given by practical and experienced friends. In working out quantities, ordinary arithmetical processes usually suffice, but long experience has suggested many little labour-saving methods of calculation, which are useful in counting and estimating rapidly and accurately.

When quoting for a tessellated pavement or floor, an inclusive price per square yard should be given, the total cost of the work being arrived at by ascertaining the area in square yards from the plan showing the tiling required.

To arrive at such an initial inclusive price per square yard, the calculation may be as follows:—

	s.	d.
Tiles, say list price per square yard,	6	0
Package,	0	6
Carriage costs, say for every 10s. of rate,	0	3
Laying (labour only, 2s. 6d. paid), reckon	3	0
(Under certain circumstances expenses for travelling, lodgings, supervising, etc., may have to be considered in these charges.)		
Portland cement,	1	0
Sand, clean river sand free from loam,	0	3
Inclusive price per square yard,	11	0

The price of the tiles fluctuates with quality, class, and selection; and if the builder requires a discount of 10 per cent., then add one-ninth to the total price. Mosaic varies so greatly, according to the fineness of the work, that no general rule can be laid down to meet all classes of this kind of work.

The estimated cost in the above figures is based upon the supposition that the foundation has already been prepared in a workman-like manner, with a ½-inch face-skimming of Roman cement and sand, and already set hard. Floors composed largely of vitreous tiles will usually be a higher cost per square yard than plain floor-tiles made of native clays, and the use of certain tints will increase the cost more than others, by reason of the greater cost of materials.

With wall-tile designs, estimates can be prepared upon a basis similar to that already described for calculating tiled floors. When the work is plain, the counting, etc., is much simplified; on the other hand, if elaborate designs are introduced, the matter is more intricate. When tiles of special design or quality are introduced, these are usually counted separately, and the whole priced accordingly.

Tilework or faience for hearths, fireplaces, mantelpieces, stoves, etc., is generally quoted at a price complete, and thus is easily calculated in an estimate.

APPENDIX A

FORM 923.
December 1903.

FACTORY AND WORKSHOP ACTS, 1891, 1895, AND 1901.

AMENDED SPECIAL RULES FOR THE MANUFACTURE AND DECORATION OF EARTHENWARE AND CHINA.

As established, after Arbitration, by the Awards of the Umpire, Lord James of Hereford, dated 30*th of December* 1901 *and* 28*th of November* 1903.

DUTIES OF OCCUPIERS.

1. Deleted.

2. After the first day of February 1904 no glaze shall be used which yields to a dilute solution of hydrochloric acid more than five per cent. of its dry weight of a soluble lead compound calculated as lead monoxide when determined in the manner described below. Lead to be in insoluble form.

A weighed quantity of dried material is to be continuously shaken for one hour, at the common temperature, with 1000 times its weight of an aqueous solution of hydrochloric acid containing 0·25 per cent. of HCl. This solution is thereafter to be allowed to stand for one hour and to be passed through a filter. The lead salt contained in an aliquot portion of the clear filtrate is then to be precipitated as lead sulphide and weighed as lead sulphate. Method of testing glaze.

If any occupier shall give notice in writing to the Inspector for the district that he desires to use a glaze which does not conform to the above-mentioned conditions, and to adopt in his factory the scheme of compensation prescribed in Schedule B, and shall affix and keep the same affixed in his factory, the above provisions shall not apply to his factory, but instead thereof the following provisions shall apply. Use of non-conforming glaze.

All persons employed in any process included in Schedule A other than china-scouring shall be examined before the commencement of their employment, or at the first subsequent visit of the Certifying Surgeon, and once in each calendar month by the Certifying Surgeon of the district. Examination.

Suspension.

The Certifying Surgeon may at any time order by signed certificate the suspension of any such person from employment in any process included in Schedule A other than china-scouring, if such Certifying Surgeon is of opinion that such person by continuous work in lead will incur special danger from the effects of plumbism; and no person after such suspension shall be allowed to work in any process included in Schedule A, other than china-scouring, without a certificate of fitness from the Certifying Surgeon entered in the register.

Casual employment.

Any workman who, by reason of his employment being intermittent or casual, or of his being in regular employment for more than one employer, is unable to present himself regularly for examination by the Certifying Surgeon, may procure himself at his own expense to be examined once a month by a Certifying Surgeon, and such examination shall be a sufficient compliance with this rule. The result of such examination shall be entered by the Certifying Surgeon in a book to be kept in the possession of the workman. He shall produce and show the said book to a Factory Inspector or to any employer on demand, and he shall not make any entry or erasure therein.

Non-observance of compensation scheme.

If the occupier of any factory to which this rule applies fails duly to observe the conditions of the said scheme, or if any such factory shall, by reason of the occurrence of cases of lead poisoning, appear to the Secretary of State to be in an unsatisfactory condition, he may, after an enquiry, at which the occupier shall have an opportunity of being heard, prohibit the use of lead for such time and subject to such conditions as he may prescribe.

Attendance at appointed time.

All persons employed in the processes included in Schedule A, other than china-scouring, shall present themselves at the appointed time for examination by the Certifying Surgeon, as prescribed in this rule.

Additional examinations.

In addition to the examinations at the appointed times, any person so employed may at any time present himself to the Certifying Surgeon for examination, and shall be examined on paying the prescribed fee.

All persons shall obey any directions given by the Certifying Surgeon.

Employment after suspension.

No person after suspension by the Certifying Surgeon shall work in any process included in Schedule A, other than china-scouring, without a certificate of fitness from the Certifying Surgeon entered in the register.

Non-attendance at monthly examination.

Any operative who fails without reasonable cause to attend any monthly examination shall procure himself, at his own expense, to be examined within fourteen days thereafter by the Certifying Surgeon, and shall himself pay the prescribed fee.

Health register.

A register, in the form which has been prescribed by the Secretary of State for use in earthenware and china works, shall be kept, and in it the Certifying Surgeon shall enter the dates and results of his visits, the number of persons examined, and particulars of any directions given by him. This register shall contain a list of all persons employed in the processes included in Schedule A, or in emptying china biscuit ware, and shall be produced at any time when required by His Majesty's Inspector of Factories or by the Certifying Surgeon.

Samples for analysis.

3. The occupier shall allow any of His Majesty's Inspectors of Factories to take at any time sufficient samples for analysis of any material in use or mixed for use.

Provided that the occupier may at the time when the sample is taken, and on

providing the necessary appliances, require the Inspector to take, seal, and deliver to him a duplicate sample.

But no analytical result shall be disclosed or published in any way except such as shall be necessary to establish a breach of these rules.

4. No woman, young person, or child shall be employed in the mixing of unfritted lead compounds in the preparation or manufacture of fritts, glazes, or colours. **Age and sex limits.**

5. No person under fifteen years of age shall be employed in any process included in Schedule A, or in emptying china biscuit ware. **Age limit.**

Thimble-picking, or threading-up, or looking-over biscuit ware shall not be carried on except in a place sufficiently separated from any process included in Schedule A.

6. All women and young persons employed in any process included in Schedule A shall be examined once in each calendar month by the Certifying Surgeon for the district. **Monthly examination.**

The Certifying Surgeon may order by signed certificate in the register the suspension of any such woman or young persons from employment in any process included in Schedule A, and no person after such suspension shall be allowed to work in any process included in Schedule A without a certificate of fitness from the Certifying Surgeon entered in the register.

7. A register, in the form which has been prescribed by the Secretary of State for use in earthenware and china works, shall be kept, and in it the Certifying Surgeon shall enter the dates and results of his visits, the number of persons examined in pursuance of rule 6 as amended, and particulars of any directions given by him. This register shall contain a list of all persons employed in the processes included in Schedule A, or in emptying china biscuit ware, and shall be produced at any time when required by H.M. Inspector of Factories or by the Certifying Surgeon. **Health register.**

8. The occupier shall provide and maintain suitable overalls and head coverings for all women and young persons employed in the processes included in the Schedule A, or in emptying china biscuit ware. **Overalls and head coverings.**

No person shall be allowed to work in any process included in the Schedule, or in emptying china biscuit ware, without wearing suitable overalls and head coverings, provided that nothing in this rule shall render it obligatory on any person engaged in drawing glost ovens to wear overalls and head coverings.

All overalls, head coverings, and respirators, when not in use or being washed or repaired, shall be kept by the occupier in proper custody. They shall be washed or renewed at least once a week, and suitable arrangements shall be made by the occupier for carrying out these requirements.

A suitable place, other than that provided for the keeping of overalls, head coverings, and respirators, in which all the above workers can deposit clothing put off during working hours, shall be provided by the occupier.

Each respirator shall bear the distinguishing mark of the worker to whom it is supplied.

9. No person shall be allowed to keep, or prepare, or partake of any food, or drink, or tobacco, or to remain during meal times in a place in which is carried on any process included in Schedule A. **Food.**

The occupier shall make suitable provision, to the reasonable satisfaction of the

Inspector in charge of the district, for the accommodation during meal-times of persons employed in such places or processes, with a right of appeal to the Chief Inspector of Factories. Such accommodation shall not be provided in any room or rooms in which any process included in Schedule A is carried on, and no washing conveniences mentioned hereafter in rule 13 shall be maintained in any room or rooms provided for such accommodation.

Suitable provision shall be made for the deposit of food brought by the workers.

Dust. 10. The processes of:—

The towing of earthenware,
China-scouring,
Ground-laying,
Ware-cleaning after the dipper,
Colour-dusting, whether on-glaze or underglaze,
Colour-blowing, whether on-glaze or underglaze,
Glaze-blowing, or
Transfer-making

shall not be carried on without the use of exhaust fans, or other efficient means for the effectual removal of dust, to be approved in each particular case by the Secretary of State, and under such conditions as he may from time to time prescribe.

In the process of ware-cleaning after the dipper, sufficient arrangements shall be made for any glaze scraped off which is not removed by the fan, or the other efficient means, to fall into water.

In the process of ware-cleaning of earthenware after the dipper, damp sponges or other damp material shall be provided in addition to the knife or other instrument, and shall be used wherever practicable.

Flat-knocking and fired-flint sifting shall be carried on only in enclosed receptacles, which shall be connected with an efficient fan or other efficient draught unless so contrived as to prevent effectually the escape of injurious dust.

In all processes the occupier shall, as far as practicable, adopt efficient measures for the removal of dust and for the prevention of any injurious effects arising therefrom.

Respirators. 11. No person shall be employed in the mixing of unfritted lead compounds, in the preparation or manufacture of fritts, glazes, or colours containing lead, without wearing a suitable and efficient respirator provided and maintained by the employer; unless the mixing is performed in a closed machine or the materials are in such a condition that no dust is produced.

Each respirator shall bear the distinguishing mark of the worker to whom it is supplied.

Ventilation. 12. All drying-stoves as well as all workshops and all parts of factories shall be effectually ventilated to the reasonable satisfaction of the Inspector in charge of the district.

Lavatories. 13. The occupier shall provide and continually maintain sufficient and suitable washing conveniences for all persons employed in the processes included in Schedule A, as near as practicable to the places in which such persons are employed.

The washing conveniences shall comprise soap, nail-brushes, and towels, and at

least one wash-hand basin for every five persons employed as above, with a constant supply of water laid on, with one tap at least for every two basins, and conveniences for emptying the same and running off the waste water on the spot down a waste-pipe.

There shall be in front of each washing-basin or convenience a space for standing-room which shall not be less in any direction than 21 inches.

14. The occupier shall see that the floors of workshops and of such stoves as are entered by the workpeople are sprinkled and swept daily; that all dust, scraps, ashes, and dirt are removed daily; and that the mangles, work-benches, and stairs leading to workshop are cleansed weekly. Cleansing of workplaces.

When so required by the Inspector in charge of the district, by notice in writing, any such floors, mangles, work-benches, and stairs shall be cleansed in such manner and at such times as may be directed in such notice.

As regards every potters' shop and stove, and every place in which any process included in Schedule A is carried on, the occupier shall cause the sufficient cleansing of floors to be done at the time when no other work is being carried on in such room, and in the case of potters' shops, stoves, dipping-houses, and majolica-painting rooms, by an adult male.

Provided that in the case of rooms in which ground-laying or glost-placing is carried on, or in the china-dippers' drying-room, the cleansing prescribed by this rule may be done before work commences for the day; but in no case shall any work be carried on in the room within one hour after any such cleansing as aforesaid has ceased.

15. The occupier shall cause the boards used in the dipping-house, dippers' drying-room, or glost-placing shop to be cleansed every week, and shall not allow them to be used in any other department, except after being cleansed. Boards.

When so required by the Inspector in charge of the district, by notice in writing, any such boards shall be washed at such times as may be directed in such notice.

Duties of Persons Employed.

16. All women and young persons employed in the processes included in Schedule A shall present themselves at the appointed time for examination by the Certifying Surgeon as provided in rule 6 as amended. Monthly examination.

No person after suspension by the Certifying Surgeon shall work in any process included in the Schedule without a certificate of fitness from the Certifying Surgeon entered in the register.

17. Every person employed in any process included in Schedule A, or in emptying china biscuit ware, shall, when at work, wear a suitable overall and head covering, and also a respirator when so required by rule 11 as amended, which shall not be worn outside the factory or workshop, and which shall not be removed therefrom except for the purpose of being washed or repaired. Such overall and head covering shall be in proper repair and duly washed. Overalls.

The hair must be so arranged as to be fully protected from dust by the head covering.

The overalls, head coverings, and respirators when not being worn, and clothing put off during working hours, shall be deposited in the respective places provided by the occupier for such purposes under rule 8 as amended.

Food. 18. No person shall remain during meal-times in any place in which is carried on any process included in Schedule A, or introduce, keep, prepare, or partake of any food or drink or tobacco therein at any time.

Ventilation. Dust. 19. No person shall in any way interfere, without the knowledge and concurrence of the occupier or manager, with the means and appliances provided by the employers for the ventilation of the workshops and stoves, and for the removal of dust.

Washing. 20. No person included in any process included in Schedule A shall leave the work or partake of meals without previously and carefully cleaning and washing his or her hands.

No person employed shall remove or damage the washing-basins or conveniences provided under rule 13.

Cleansing of workplaces. 20A. The persons appointed by the occupiers shall cleanse the several parts of the factory regularly as prescribed in rule 14.

Avoidance of dust, dirt, etc. Every worker shall so conduct his or her work as to avoid, as far as practicable, making or scattering dust, dirt, or refuse, or causing accumulation of such.

Boards. 21. The boards used in the dipping-house, dippers' drying-room, or glost-placing shop shall not be used in any other department, except after being cleansed, as directed in rule 15.

Disuse of lead. 22. If the occupier of a factory to which these rules apply gives with reference to any process included in Schedule A, other than china-scouring, an undertaking that no lead or lead compound or other poisonous material shall be used, the Chief Inspector may approve in writing of the suspension of the operation of rules 4, 5, 6, 7, 8, 15, 16, 17, and 21, or any of them in such process; and thereupon such rules shall be suspended as regards the process named in the Chief Inspector's approval, and in lieu thereof the following rule shall take effect, viz., no lead or lead compound or other poisonous material shall be used in any process so named.

For the purpose of this rule materials that contain no more than one per cent. of lead shall be regarded as free from lead.

SCHEDULE A.

Dipping or other process carried on in the dipping-house.
Glaze-blowing.
Painting in majolica or other glaze.
Drying after dipping.
Ware-cleaning after the application of glaze by dipping or other process.
China-scouring.
Glost-placing.
Ground-laying.

Colour-dusting } whether on-glaze or underglaze.
Colour-blowing }

Lithographic transfer making.

Making or mixing of fritts, glazes, or colours containing lead.

Any other process in which materials containing lead are used or handled in the dry state, or in the form of spray, or in suspension in liquid other than oil or similar medium.

SCHEDULE B.

Notice to Workmen employed in Processes named in Schedule A, other than China-Scouring.

Conditions of Compensation.

1. Where a workman is suspended from working by a Certifying Surgeon of the district on the ground that he is of opinion that such person by continued work in lead will incur special danger from the effects of plumbism, and the Certifying Surgeon shall certify that in his opinion he is suffering from plumbism arising out of his employment, he shall, subject as hereinafter mentioned, be entitled to compensation from his employer as hereinafter provided.

(*a*) If any workman who has been suspended as aforesaid dies within nine calendar months from the date of such certificate of suspension, by reason of plumbism contracted before the said date, there shall be paid to such of his dependants as are wholly dependant upon his earnings at the time of his death, or upon the weekly compensation payable under this scheme, a sum equal to the amount he has earned during a period of three years next preceding the date of the said certificate, such sum not to be more than £300 nor less than £150 for an adult male, £100 for an adult female, and £75 for a young person.

(*b*) If the workman does not leave any dependants wholly dependant as aforesaid, but leaves any dependants in part dependant as aforesaid, a reasonable part of that sum.

(*c*) If he leaves no dependants, the reasonable expenses of his medical attendance and burial, not exceeding ten pounds.

2. With respect to such payments the following provisions shall apply:—

(*a*) All sums paid to the workman as compensation since the date of the said certificate shall be deducted from the sums payable to the dependants.

(*b*) The payment shall, in case of death, be made to the legal personal representative of the workman, or, if he has no legal personal representative, to or for the benefit of his dependants, or, if he leaves no dependants, to the person

to whom the expenses are due; and if made to the legal personal representative, shall be paid by him to or for the benefit of the dependants or other person entitled thereto.

(*c*) Any question as to who is a dependant, or as to the amount payable to each dependant, shall in default of agreement be settled by arbitration as hereinafter provided in clause 9.

(*d*) The sum allotted as compensation to a dependant may be invested or otherwise applied for the benefit of the person entitled thereto, as agreed, or as ordered by the arbitrator.

(*e*) Any sum which is agreed or is ordered by the arbitrator to be invested may be invested in whole or in part in the Post Office Savings Bank.

3. Where a workman has been suspended and certified as provided in condition 1, and while he is totally or partially prevented from earning a living by reason of such suspension, he shall be entitled to a weekly payment not exceeding fifty per cent. of his average weekly earnings at the time of such suspension, such payment not to exceed £1. The average may be taken over such period, not exceeding twelve months, as appears fair or reasonable having regard to all the circumstances of the case.

4. In fixing these weekly payments, regard shall be had to the difference between the amount of the average weekly earnings of the workman at the time of his suspension and the average amount, if any, which it is estimated that he will be able to earn afterwards in any occupation or employment, and to any payments (not being wages) which he may have received from the employer in respect of the suspension, and to all the circumstances of the case, including his age and expectation of life.

5. If it shall appear that any workman has persistently disobeyed the special rules or the directions given for his protection by his employers, and that such disobedience has conduced to his suspension, or has not presented himself for examination by the Certifying Surgeon, or has failed to give full information and assistance as provided in condition 6, his conduct may be taken into consideration in assessing the amount of the weekly payments.

6. It shall be the duty of every workman at all times to submit to medical examination when required, and to give full information to the Certifying Surgeon, and to assist to the best of his power in the obtaining of all facts necessary to enable his physical condition to be ascertained.

7. Any weekly payment may be reviewed at the request either of the employer or of the workman, and on such review may be ended, diminished, or increased, subject to the maximum above provided; and the amount of payments shall, in default of agreement, be settled by arbitration.

8. Any workman receiving weekly payments under this scheme shall submit himself if required for examination by a duly qualified medical practitioner provided and paid by the employer.

If the workman refuses to submit himself to such examination, or in any way obstructs the same, his right to such weekly payments shall be suspended until such examination has taken place.

9. If any dispute shall arise as to any certificate of the Certifying Surgeon, or as to the amount of compensation payable as herein provided, or otherwise in relation to these provisions, the same shall be decided by an arbitrator to be appointed by the employer and workman, or in default of agreement, by the Secretary of State. The said arbitrator shall have all the powers of an arbitrator under the Arbitration Act, and his decision shall be final.

The fee of the arbitrator shall be fixed by the Secretary of State, and shall be paid as the arbitrator shall direct.

10. No compensation shall be payable under these provisions unless a claim in writing is made within six weeks of the date of the certificate of suspension, or of the death, provided that the want of such notice shall not bar the claim if in the opinion of the arbitrator there was reasonable excuse for the want of it.

A claim for compensation by any workman whose employment is intermittent, or casual, or who is regularly employed by more than one employer, shall only arise against the employers for whom he has worked in a process included in Schedule A within one month prior to his suspension. The said employers shall bear the compensation among them in such proportion as in default of agreement shall be determined by an arbitrator as herein provided.

11. "Employer" includes an occupier, a corporation, and the legal representatives of a deceased employer. "Workman" includes every person, male or female, whether his agreement be one of service or apprenticeship or otherwise, and is expressed or implied, orally or in writing, and shall include the personal representatives of a deceased workman. "Dependants" has the same meaning as in the Workmen's Compensation Act, 1897.

The terms contained in this notice shall be deemed to be part of the contract of employment of all workmen in the above-named processes.

Occupier's Signature ____________________

APPENDIX B

SUGGESTIONS FOR SETTING TILE.

As officially compiled by the Tile Manufacturers of the United States of America, November 1900.

(Reprinted in this volume by special permission.)

LIST OF TILE MANUFACTURERS AUTHORIZING THESE SUGGESTIONS.

American Encaustic Tiling Co., Ltd., Zanesville, Ohio.
Beaver Falls Art Tile Co., Ltd., Beaver Falls, Pa.
Cambridge Tile Manufacturing Co., Covington, Kentucky.
Columbia Encaustic Tile Company, Anderson, Ind.
C. Pardee Works, Perth Amboy, N.J.
Maywood Art Tile Company, Maywood, N.J.
Mosaic Tile Company, Zanesville, Ohio.
New York Vitrified Tile Co., Brooklyn, N.Y.
Old Bridge Enamelled Brick and Tile Co., Old Bridge, N.J.
Providential Tileworks, Trenton, N.J.
Robertson Art Tile Company, Morrisville, Pa.
Star Encaustic Tile Company, Pittsburg, Pa.
Trent Tile Company, Trenton, N.J.
United States Encaustic Tileworks, Indianapolis, Ind.

The "Suggestions for Setting Tile" contained in the following pages are made for the purpose of improving tilework and bringing the standard up to a more uniform basis, giving to those in sections of the country where tile is not in general use the necessary information to secure first-class work, thereby creating an increased demand.

By following these "Suggestions" the manufacturers of tile can guarantee first-class and satisfactory work, as the details have been most carefully prepared.

The principal object in laying this matter before those interested in perfect tilework is to point out the proper method of insuring, in a short time, as large a consumption

of tile as we now find in foreign countries, as the tile industry of this country, when compared with European countries, is in its infancy.

Trusting that all will appreciate the good intentions of these "Suggestions," and preserve them for future reference, we remain,

Most respectfully,

THE TILE MANUFACTURERS OF THE U.S.

Foundations.—A good foundation is always necessary, and should be both solid and perfectly level. Tile should always be laid upon a concrete foundation, prepared from the best quality Portland cement and clean sharp sand and gravel, or other hard material. (CINDERS SHOULD NEVER BE USED, AS THEY HAVE A TENDENCY TO DESTROY THE LIFE OF THE CEMENT AND CAUSE IT TO DISINTEGRATE.) A foundation, however, may also be formed of brick or hollow tile imbedded solidly in, and covered with cement mortar. Concrete should be allowed to thoroughly harden before laying the floor, and should be well soaked with water before laying the tile.

Lime Mortar should never be mixed with concreting.

Concrete should consist of

One part Portland cement,
Two parts clean sharp sand,
Two parts clean gravel,

and thoroughly mixed with sufficient water to form a hard, solid mass when well beaten down into a bed, which should be from $2\frac{1}{2}$ inches to 3 inches thick.

If the concrete bed can be made *over three inches in thickness*, the concrete can then be made of

One part Louisville cement,
One part clean sharp sand,
One part clean gravel,

and thoroughly mixed with sufficient water as above directed.

For Floors, the surface of the concrete must be level and finished to within 1 inch of the finished floor line, when tile $\frac{1}{2}$-inch thick is used, which will leave a space of $\frac{1}{2}$-inch for cement mortar, composed of equal parts of the very best quality Portland cement and clean sharp sand. The distance below the surface of the finished floor line, however, should be governed by the thickness of the tile.

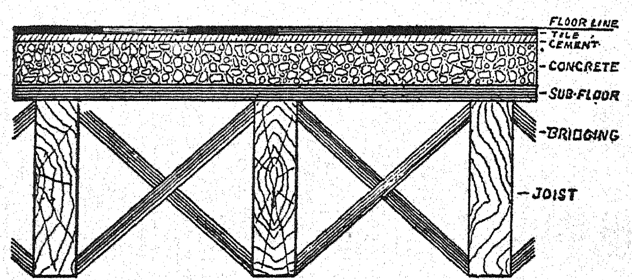


FIG. I.

For Wood Floors.—When tiles are to be laid on wood flooring in new buildings, the joists should be set 5 inches below the intended finished floor line and spaced about 12 inches apart and thoroughly

bridged, so as to make a stiff floor, and covered with 1-inch rough boards not over 6 inches wide (boards 3 inches wide preferred), and *thoroughly nailed*, and the joints $\frac{1}{8}$-inch apart to allow for swelling. (See fig. 1.) (A layer of heavy tar paper on top of wood flooring will protect the boards from the moisture of the concrete, and will also prevent any moisture from dripping through to a ceiling below.)

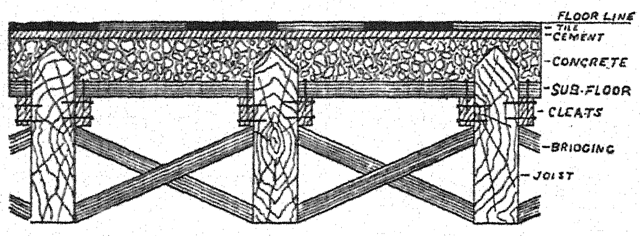


FIG. 2.

In Old Buildings.—Cleats are nailed to joists 5 inches below the intended finished floor line, and short pieces of boards $\frac{1}{8}$-inch apart fitted in between the joists upon the cleats and well nailed, and the joists thoroughly bridged. The corners on the upper edge of the joists should be chamfered off to a sharp point (see fig. 2), as the flat surface of the joists will give an uneven foundation. When the strength of the joists will permit, it is best to cut an inch or more off the top. (Where joists are too weak, strengthen by thoroughly nailing cleats 6 inches wide full length of joists.) When the solid wood foundation is thus prepared, concrete is placed upon it as above directed.

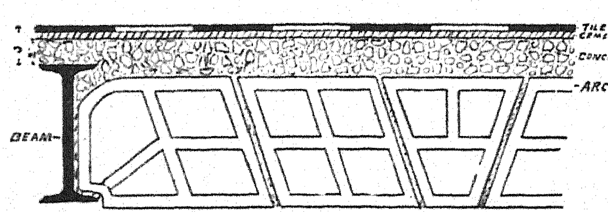


FIG. 3.

Where Steel Beams and hollow tile arches are used, frequently very little space is left for preparing a proper foundation for setting tile, as the rough coating is usually put in by the hollow tile contractor to protect his work, but this covering should always conform to the requirements for a solid tile foundation. Should this not be the case, the tile contractor should remove sufficient of the covering to allow him to put down a foundation that will insure a satisfactory tile-floor. (Cinders, lime, mortar, or inferior material must never be used.)

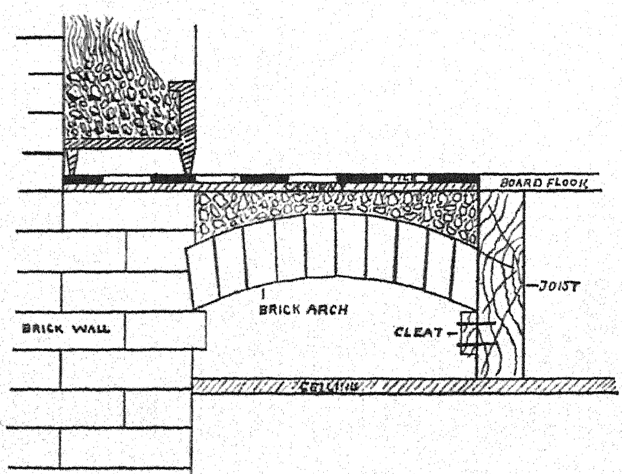


FIG. 4

THE TOPS OF IRON BEAMS SHOULD BE FROM THREE TO FOUR INCHES BELOW THE FINISHED FLOOR LINE, TO PREVENT FLOORS WHEN FINISHED SHOWING LINES OF THE BEAMS.

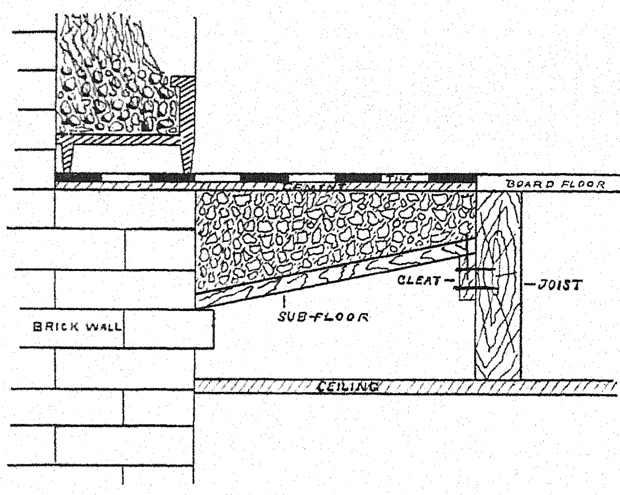


FIG. 5.

For Hearths.—The foundation for hearths should be placed upon a brick arch, if possible, to insure perfect fire protection, and then covered with concrete in the same manner as directed for tile-floors. If placed upon a sub-foundation of wood, the concreting should be at least 6 inches thick. (See figs. 4 and 5.)

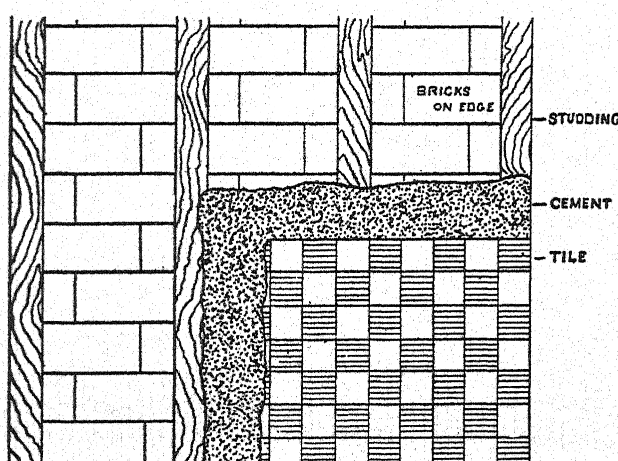


FIG. 6.

For Walls.—When tiles are to be laid on old brick walls the plaster must be all removed and the mortar raked out of the joints of the brickwork to form a key for

the cement. On new brick walls the joints should not be pointed. When tiles are to be placed on studding, the studding should be well braced by filling in between the studding with brick set in mortar to the height of tilework (see fig. 6); or brick-work may be omitted and extra studding put in and thoroughly bridged, so as to have as little spring as possible, and this studding then covered with sheet-metal lathing. (See fig. 7.) (TILE MUST NEVER BE PLACED ON WOOD LATH OR ON OLD PLASTER.) The brick walls must be well wet with water and then covered with a rough coating of cement mortar, composed of one part Portland cement and two parts clean sharp sand. When tiles are placed on metal lathing, hair should be mixed with the cement mortar to make it adhere more closely to the lath. The cement mortar should be $\frac{1}{2}$ inch thick, or sufficient to make an even and true surface to within 1 inch of the intended finished surface of the tile, when tile $\frac{1}{2}$ inch thick is used, which will allow a space of $\frac{1}{2}$ inch for the cement mortar, composed as above for rough-coating the walls. The face of the cement foundation should be roughly scratched, and allowed to harden for at least one day before commencing to lay the tile. If any lime is mixed with the cement mortar for setting the tiles, *it should never exceed* 10 *per cent.*, and great care must be used to have the *lime well slacked*, and made free from all lumps by running through a coarse sieve, in order to guard against "heaving" or "swelling," and thus loosening or "lifting" the tiles.

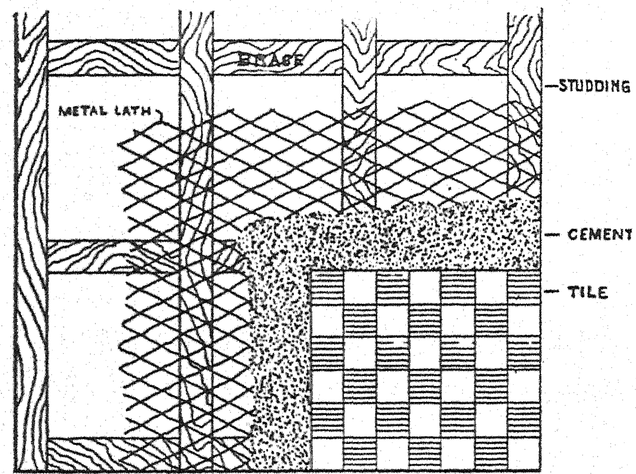


FIG. 7.

IMPORTANT.—The foundation for both floor and wall tiling should be thoroughly brushed, to remove all dust and small particles adhering to it, and then well wet before putting on the cement mortar. To insure a perfect bond it is best to coat the foundation by brushing over it pure cement mixed in water.

Materials.—*Cement.*—The very best quality of Portland cement should always be used for setting either floor or wall tile and for grouting the floors, and the very best quality of Keene's imported cement for filling the joints in the wall-tiling.

Sand.—Clean sharp grit sand, free from all salt, loam, or other matter, and perfectly screened before mixing with the cement, should always be used.

Mortar, for floor or vitreous tiles, should be composed of equal parts of cement and sand, and for wall-tiles one part of cement and two parts sand. The mortar should not be too wet, but should be rather stiff, and should always be used fresh; as mortar, when allowed to set before using, loses a portion of its strength.

Soaking.—Tiles must always be thoroughly soaked in water before setting, which makes the cement unite to the tiles.

Setting.—*The Tiles for the Floors* are first laid out to ascertain if they are all right, and compared with the plan provided for laying the floors. Strips are then set, beginning at one end of and in the centre of the room, and level with the intended finished floor line. Two sets of guide-strips running parallel about 18 to 30 inches apart should be set first. (See fig. 8.) The mortar is then spread between them for about 6 to 10 feet at a time, and levelled with a screed notched at each end, to allow for the thickness of the tiles. (See fig. 9.) The tiles are placed upon the mortar, which must be stiff enough to prevent the mortar from working up between the joints. The tiles are to be firmly pressed into the mortar and tamped down with a block and hammer until they are exactly level with the strips. When the space between the strips is completed, the strip on one side of the tile is moved out 18 to 30 inches and placed in proper position for laying another section of tile, using the tiles which have been laid for one end of the screed, and the laying of the tile continued in the same manner until the floor is finished. When the cement is sufficiently set, which should be in about two days, the floor should be well scrubbed with clean water and a broom, and the joints thoroughly grouted with pure cement (mixed with water to the consistency of cream). As soon as this begins to stiffen, it must be carefully rubbed off with sawdust or fine shavings, and the floor left perfectly clean.

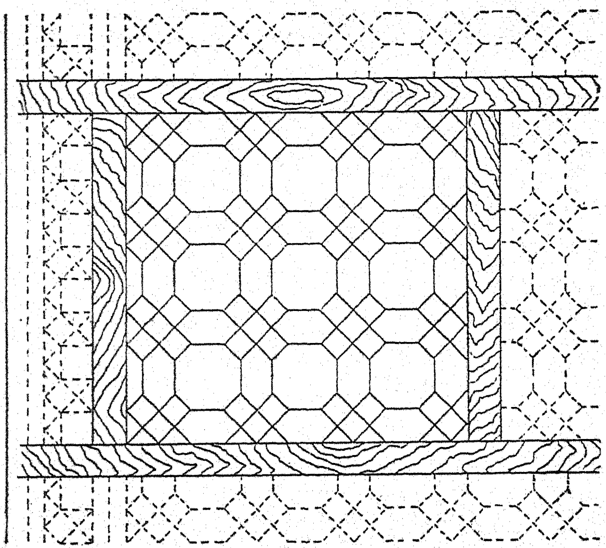


FIG. 8.

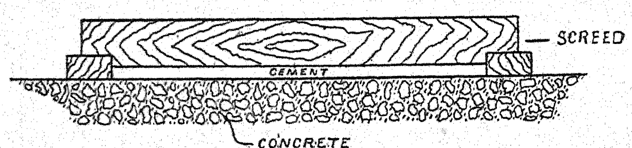


FIG. 9.

Ceramics.—The foundation and cement mortar for ceramics are the same as for plain or vitreous floors, and the guide-strips used in the same manner. The cement mortar is then spread evenly, and the tile-sheets laid carefully on it with the paper side up. After the batch is covered, the tile-setter should commence to press the tile into the mortar, gently at first, firmly afterwards, using block and hammer, thus leveling the tile as correctly as possible. The tile should be beaten down until the mortar is

visible in the joints through the paper, however without breaking it. The paper is then moistened, and after it is well soaked and can be easily removed, it is pulled off backwards, starting from a corner. After removing the paper, the tile should be sprinkled with white sand before finishing the beating, so that the tiles will not adhere to the beater, owing to the paste which is used in mounting them. Corrections of the surface are then made by leveling it with block and hammer. The filling of the joints and cleaning of the surface is a delicate operation, as the looks of this work depend largely upon it. The joints are to be filled with clean Portland cement mixed with water. This mixture is forced into the joints with a flat trowel (not with a broom, which often scrapes out the joints). After the joints are filled, the surplus cement is removed from the surface by drawing a wet piece of canton flannel over it. This piece of cloth must be washed out frequently with clean water. After the floor is cleaned, it should be allowed to stand for a day or two, when the whole floor is to be rubbed with sharp sand and a board of soft lumber. This treatment, which removes the last traces of cement, is preferable to the washing off with an acid solution, as it will not attack the cement in the joints. In laying the tile-sheets on the cement, care should be taken to have the width of joints spaced the same as the tile on the sheets to prevent the floor having a block appearance.

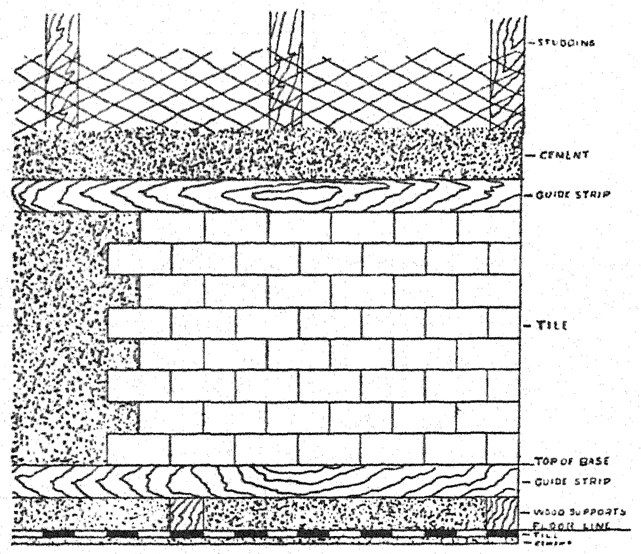


FIG. 10.

The Tiles for the Walls or Wainscoting are first laid out and compared with the plan provided for setting them. Guide-strips are then placed on the wall parallel and about 2 feet apart, the bottom one being so arranged as to allow the base to be set after the body is in place. (See fig. 10.) When a cove base is used it may be necessary to set it first, but in all cases must be well supported on the concrete. (See fig. 11.) The strips must be placed plumb and even with the intended finished wall line. The method of setting wall-tile is governed to some extent by the conditions of the wall on which they are to be set, and must be decided by the mechanic at the time which process he will use, whether buttering or floating, as equally good work can be done by either, by following the instructions as stated below.

Floating Wall-Tile.—The mortar is spread between the guide-strips for about 5 feet at a time, and leveled with a screed notched at each end to allow for the thick-

ness of the tile. (See fig. 9.) The tiles are placed in position and tamped until they are firmly united to the cement and level with the strips. When the space between the strips is completed, which should be one side of the room, the strips are removed and the work continued in the same manner until completed. When the tiles are all set, the joints must be carefully washed out and neatly filled with thinly mixed pure Keene's cement, and all cement remaining on the tile carefully wiped off.

Buttering Wall-Tiles.—The cement mortar is spread on the back of each tile, and the tile placed on the wall, and tapped gently until firmly united to the wall and plumb with the guide-strips. When the tiles are all set, the joints must be carefully washed out and filled with Keene's cement, and the tiles cleaned as directed above.

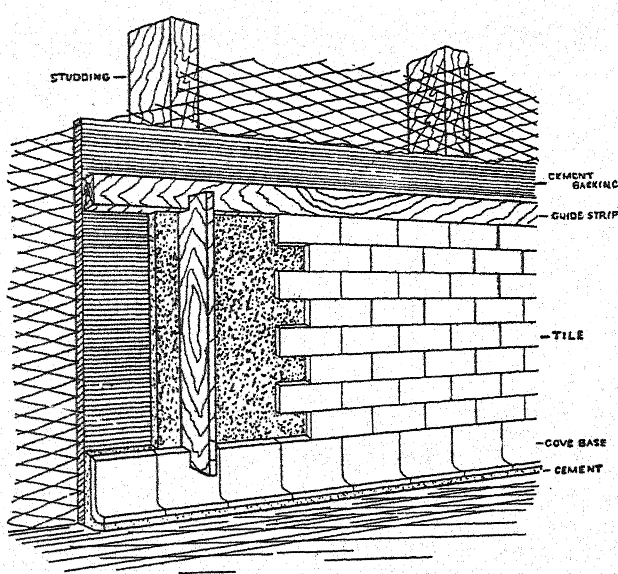


FIG. 11.

When Fixtures of any kind are to be placed on the tilework, such as plumbing in bath-room, provision should be made for them by fastening wood strips on the wall before the rough or first coating of cement mortar is put on, the strips to be the same thickness as the rough coating. The tiles can be placed over the strips by covering them with cement mortar, and, when thoroughly set, holes can be bored in the tiles for fastening the fixtures without injuring the tiling.

Hearth and Facing Tile are set in the same manner as for floors and walls.

Cleaning.—It is absolutely necessary to remove with sawdust, and afterwards with a flannel cloth and water, all traces of cement which may have been left on the surface of the tile, as it is hard to remove after it is set.

After thoroughly cleaning the floor, it should be covered with sawdust and boards placed on the floor for several days where there is walking upon it.

A white scum sometimes appears on the surface of the tile, caused by the cement. This can generally be removed by washing frequently with plenty of soap and water. If this does not remove it, then use a weak solution of 15 parts muriatic acid and 85 parts water, which should only be allowed to remain on the tile for a few minutes, and then thoroughly washed off.

Cutting of Tile.—When it is found necessary to cut tile the following directions are given:—

Tools.—The chisels used should be made of the best tool steel, and should always

be sharp. They should be of small size, the edge not being wider than ¼-inch. The hammer should be light, weighing about 6 ounces, having a slender handle. After the exact shape of the tile has been determined, lines should be drawn on the surface of the tile with a lead pencil, giving the exact direction of the cut desired. This line should be followed with the chisel, which is held at right angles with the surface, the hammer giving the chisel sharp decisive raps. After the line has been repeatedly traversed with the chisel, a few sharp blows against the back of the tile opposite the mark on the face will break it at the place thus marked.

To cut glazed or enamel tiles, they should be scratched on the surface with a tool at the place where it is desired to break them, and then gently tapped on the back opposite the scratch.

Caution should be used not to allow anyone to walk upon or carry anything heavy over the floor, or have any pounding about wall-work for several days, or until the tiles are firmly set. Unless these precautions are taken, it will be impossible to guarantee a first-class job. Tilework is frequently condemned when the fault lies with the rush of other contractors to finish their work.

General Information.—

Concrete.	1 part Portland cement, 2 parts sharp sand, 2 ,, clean gravel,	1 square foot 3 inches thick,	Weighs 33 lbs.
Cement Mortar.	1 part Portland cement, 1 ,, sharp sand,	1 square foot ½-inch thick,	Weighs 6½ lbs.
Tile.	White vitreous,	1 square foot ½-inch thick,	Weighs 6 lbs.

Total weight of 1 square foot of floor and foundation weighs 45½ lbs.
12-inch joists, 12-inch center to center, 16-feet limit of span.
10-inch joists, 12-inch center to center, 12-feet limit of span.
8-inch joists, 12-inch center to center, 8-feet limit of span.

When longer spans are used with these sizes, they should be supported with girder and post.

APPENDIX C

NOTES ON THE TILE DECORATION FOUND ON BUILDINGS IN PUNJAB AND BENGAL.[1]

By J. H. MARSHALL, Esq., Director-General of Archæology, India.

SIMLA, *16th June* 1904.

NOTE ON TILE DECORATION FOUND ON BUILDINGS IN THE PUNJAB.

The tiles found on buildings in the Punjab are of three kinds:—

1. The earliest type—judging from the date of buildings on which it occurs—is that of the Western Punjab. The tomb of Ruku-i-'Alam at Multán is the most prominent specimen. The saint whose name it bears was a contemporary of Ghiyās-ud-dín Tughlaq Sháh (A.D. 1320–24) and his son Muhammad Tughlaq (A.D. 1324–51).

"The Ruku-i-'Alam is built entirely of red-brick, bonded with beams of *Sisu* wood which are now much decayed. The whole of the exterior is elaborately ornamented with glazed tile panels and string courses and battlements. The only colours used are dark blue, azure, and white, but these are contrasted with the deep red of the finely polished bricks, and the result is both effective and pleasing. These mosaics are not like those of later days, mere plain surfaces, but the patterns are raised from half an inch to two inches above the background. This mode of construction must have been very troublesome, but its increased effect is undeniable, as it unites all the beauty of variety of colour with the light and shade of a raised pattern." (Cunningham, *Archæological Survey Report*, v., p. 132. See also Plate XXXIX.)

Other instances of similar tile decoration are found on the tombs of the Nahars ("the wolves")—an 'Afghán dynasty that ruled at Sitpur (Muzaffargarh district) at the time of the Lodis, fifteenth century. (*Cf.* Darmesteter, *Chants populaires des Afghans*, clxxii.) Besides the colours enumerated by General Cunningham above, we find yellow tile used at Sitpur. (*Cf.* my *Annual Progress Report for the year ending 31st March 1902*, Appendix D.)

[1] Received too late for inclusion in the body of the work.

2. The second kind of tile-work is that largely found at Delhi, and still more at Lahore, locally known by the name of *Kāshī* or *Chīnī*. The former designation has been supposed to be derived from Kāshān, a town in Persia famous for its *faience*. Whether this may be correct or not, it seems highly probable that the art was introduced from Persia. This would explain its prevalence at Lahore. Another cause certainly is that in the capital of the Punjab stone is not easily procurable, and so this kind of decoration was largely resorted to instead of carved marble and sandstone found at Agra and Delhi. The earliest specimens occur in Delhi on buildings of the late Pathān period, such as the Moth-ki-Masjid and the mosque of the Sher Sháh at Indrapat. But on these buildings it is but very sparingly used, almost exclusively on the domes of kiosks and cupolas. The same is the case with monuments of the early Moghul period, such as the tomb of Hūmāyūn. It is only in the reign of Shāhjahán, A.D. 1627–1658, that this mode of decoration is adopted largely for wall surfaces, of which the most noticeable instance is the Wazir Khān's mosque at Lahore. Mr. Lockwood Kipling devoted an article to it in the *Journal of Indian Art and Industry*, 1887, No. 19, in which he deals especially with the technique of the *kāshī* work. In the same journal for July 1903 there is an article on the Wazīr Khān's mosque by Mr. Andrew. The colours used are the following:—

Cobalt or French blue (*lājvard*, i.e. lapis lazuli).
Cœrulean blue (*firozī*, i.e. turquoise blue).
Green (*sabaz*).
Orange (*sunahra*).
Yellow (*zard*).
White (*sufaid*).
Purple (*jámni*).

On walls almost invariably the full scheme of colours is used. The designs are either geometrical or foliated. In one case—the wall of the Lahore Palace—figures of living beings are introduced. On domes we find as a rule only one or sometimes two colours. Instances of the latter are the tomb of Dāī Angā (A.D. 1671) and that of Khán-i-khánan (A.D. 1778), both situated on the road to Shálámár. The mosque of Dāī Angā at the same palace (A.D. 1635) is, as far as I know, the only case at Lahore in which *kāshī* decoration is found in the interior of a building. After the seventeenth century but rare instances of this kind of tile-work are met with in the Punjab, and by this time the art has become completely lost. In Persia it seems to be practised up to the present day.

3. A third kind of tiles is found on buildings of the eighteenth century, such as the mosque of Muhammad Amīn at Lahore (beginning eighteenth century) and the mosque of Zakariya Khān at Begampura, near Lahore. The founder of the latter was a viceroy of the Punjab from A.D. 1717 to 1738. It is strange to find the same type combined with *kăshī* work on the tomb of Asaf Khán at Shahdara as early as A.D. 1634. The tiles of this class are square. They form, consequently, not a tile-mosaic as the two earlier types, in which each separate piece has its own shape and colour, but are similar to the tiles known in Europe, from where presumably they were introduced into

India. The colours are faint as compared to those of the *kāshī* tiles, pale green, blue, and yellow being the most prominent. In one case, the tomb of Sharf-un-nissa, known as the cypress tomb (*Sarv-vālī-maqbara*, not far from Begampura, near Lahore, we find, besides *kāshī* work on the lower part of the walls, square blue and white tiles of a type well known in the west of Europe. This building also would seem to belong to the eighteenth century.

It would be interesting to know whether there exists any connection between the use of such tiles in the Punjab and the visit of an ambassade of the Dutch East India Company to Lahore in A.D. 1712. It should be noted that at present square white and blue tiles are fabricated in great number at Multán, which are now commonly used to decorate graves with, but are entirely different from the tiles found in the ancient buildings mentioned above, *sub* 1.

Note on the Tile Decoration found on Buildings in Bengal.

Tiles were largely used in Bengal for building purposes, owing to the absence of stones. The best specimens of ornamented bricks are to be seen at Gaur and Panduah, the ancient capital. The finest are on the Tantipara mosque, which was built in 1480 A.D. At many other places ornamented bricks may be found. The mouldings generally were cut with the chisel, in imitation of the stone pattern. The art still exists, and has been employed in restoring the ruins at Gaur and Panduah. Other ornamented bricks used in Hindu temples, and exhibiting small relief scenes from human life, mostly mythological, appear to me to have been prepared in a mould. The finest temple of this kind is that at Kantonagar in the district of Dinajpur, built about 1740 A.D. by one of the ancestors of the present Maharaja of Dinajpur. The work still can be done by the men from Krishnagar, who are famous for manufacturing clay figures. Glazed tiles were much employed at Gaur, but unfortunately later generations showed a great predilection for them, and on this account very few of the buildings containing them have been left. The best specimens still may be seen at the Lakan mosque, 1485 A.D. The colours generally used are: white, blue, green, and yellow. Red is seldom met with ; white and blue predominated.

Unfortunately I have no specimens of any kind of ornamented tiles, but the Indian Museum has received a fairly good supply, and the Trustees probably will consent to part with a few ones, especially glazed tiles, for chemical examination. It would, I think, serve no useful purpose to add a list of all the places and buildings where ornamented tiles have been found or still exist, together with their dates. Their manufacture appears to me uniform, and I have not been struck with any difference except that already noted, viz., that some have been chiselled out, while others were cast in a mould. The art is very old in Bengal, and certainly was known before the Muhammadan conquest, who merely employed Bengali workmen. Hindu temples of any considerable age have not yet been found in Bengal, and are not likely to turn up.

EXTRACT from a letter from Dr. T. BLOCH, Archæological Surveyor, Bengal, dated 1st December 1903:—

"I have just returned from a visit to the ruins of Gaur and Panduah, where I picked up twelve specimens of glazed tiles :—

. . . .

"Nos. 1–8 are from the Lattan Masjid, Gaur, the date of which I have noted in my previous letter.

"Nos. 9 and 10 are from a gateway south of the Kadam Rasul, Gaur, the date of which probably was somewhere between 1530 and 1550 A.D.

"Nos. 11 and 12 come from a field at Panduah. It is not possible to give their date, but the building to which they belonged may date from the palmy days of Panduah, which lay between 1350 and 1450 A.D."

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